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LOW ALTITUDE LARGE SCALE RECONNAISSANCE: A METHOD OF OBTAINING HIGH RESOLUTION VERTICAL PHOTOGRAPHS FOR SMALL AREAS

James W. Walker

and

Steven L. De Vore

REVISED EDITION

1995

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ABSTRACT

Low altitude large scale reconnaissance (LALSR) has grown from a marriage of engineering design, photo interpretation, radio controlled model aircraft, and photography. It has the capability of vertical high resolution recording of small areas for analysis. This volume is an attempt to pull all these disciplines together in such a way as to make LALSR a useful tool to all who have the need for it. It is not an answer to all reconnaissance problems, just another tool to use in the field.

ACKNOWLEDGEMENTS

As in any endeavor, this volume is not the work of one individual. Many listed below could be co-editors. It started 23 years ago when two associates suggested there was a better way to photograph close to the ground from the air. Their encouragement and the challenge of others have been greatly appreciated. To Ray Matheny, Thomas Hinckley, Arthur Ireland, Larry Gillen, Jim Judge, Jake Hoffman, and Bill Butler, I give thanks for being those people. Special thanks to Jule Caylor for his constant challenging without ever being offensive. His constant positive questioning will make this book outdated before it ever gets into print. Wally Barrus had to teach me to fly the machines. His patience with a one eyed photographer never ceased to amaze me. Special thanks goes to my "Boss," Dean vanUitert who has more faith in me than I do. Special help and understanding came from our editors, Don Norton, Kim Greenhaugh, and Kekoa Kaluhiokalani who make the whole thing understandable. And last but not least, my undying gratitude goes to my wife, Marlene, to whom I will be eternally grateful. To her and our children goes the "Medal of Patience."

Ninety-five percent of all the LALSR imagery used in this book were originally in color.

James W. Walker
1995

TABLE OF CONTENTS

PART 1: INTRODUCTION AND BACKGROUND

CHAPTER 1 HISTORY AND BACKGROUND 1

CHAPTER 2 DESIGN OF THE DATA ACQUISITION SYSTEM 9
- A. Large Scale 12
- B. High Quality 12
- C. Low Altitude 13
- D. Low Velocity 13
- E. Low Vibration 14

CHAPTER 3 SYSTEM DESIGN 15
- A. Low Velocity 15
- B. Small Take-off and Landing Space 16
- C. Portability 17
- D. Low Cost 19
- E. Low Vibration 20
- F. Low Risk 20
- G. Low Impact 20

CHAPTER 4 SUMMARY 21

PART 2: AIRCRAFT CONSTRUCTION AND MAINTENANCE

CHAPTER 5 CONSTRUCTION TECHNIQUES 23
- A. Work Area 24
- B. Tools 24
- C. Construction Supplies 27
- D. Butterfly Construction 27
- E. Telemaster Construction 28
- F. Weight and Balance 32

CHAPTER 6 CAMERA MOUNT FOR DYNAFLITE BUTTERFLY 35
  A. Building the Mount 36
  B. Center of Gravity Alignment 39
  C. Tuning 40
  D. Materials Needed 44
  E. Tools Needed 45

CHAPTER 7 TELEMASTER MOUNT 47
  A. Construction 47
  B. Loading, Fitting, and Flying 50
  C. Oblique Mount 53
  D. Materials Needed 57
  E. Tools Needed 57

CHAPTER 8 UU & UU-2 AIRCRAFT 59
  A. 11.9 Inches 60
  B. Performance 62
  C. Resultant Design Changes 62
  D. Result of UU and UU-2 Flights 66

CHAPTER 9 CAMERA SWITCHING SYSTEM 69

CHAPTER 10 FLYING AND FLIGHT TRAINING 73
  A. Speed 73
  B. Power 73
  C. Flying 74
  D. Altitude Measurement 74
  E. Flying with Weight 78
  F. Camera on Board 79
  G. Landing 80
  H. Meteorology (Macro and Micro) 80
  I. Checklists 82
  J. Flight Log Records 84

PART 3: PRACTICAL CONSIDERATIONS

CHAPTER 11 IMAGE MOTION PROBLEM 85
  A. IMP 85
  B. Film and Camera Effects on IMP 85

C. System Resolution 87
D. The Aircraft 87
E. Actual and Calculated IMP 88
F. Mathematics and IMP 89
G. Summary 92

CHAPTER 12 IMAGE MATH 93
A. Motion 93
B. Scale 94
C. Altitude 95
D. Coverage 96
E. Overlap 96
F. Summary 96

CHAPTER 13 MISSION PLANNING, SURVEYING, AND FLYING 97
A. Flight Planning 97
B. Targeting 98
C. Surveying 103
D. Ground Truth 104
E. Film 104
F. Flying and Flight Lines 104

CHAPTER 14 PLOTTING 107
A. Cataloging 107
B. Area Plotting 107
C. Uncontrolled Mosaics 110
D. Pixel Detailing 111

CHAPTER 15 ANALYSIS AND IMAGE INTERPRETATION 113
A. Background 113
B. Basics of Image Interpretation 113
C. Interpretation 113
D. Samples of Interpretation 115
E. Summary 121

CHAPTER 16 TEACHING LALSR IN THE CLASSROOM 123
A. Text and Published Materials 124
B. Class Outline 124

PART 4: PHOTOGRAPHIC CONSIDERATIONS

CHAPTER 17 CAMERAS 125
- A. Weight 126
- B. Environmental Effects 126
- C. Service 126
- D. Quality 126
- E. Required Modification 126
- F. Cost 127
- G. Camera Test Program 127

CHAPTER 18 FILM 131
- A. Black and White Films 131
- B. Color Negative Films 131
- C. Color Transparency Films 132
- D. Special Emulsion Films 132
- E. Film Speed 132
- F. D-X Cassette Problems 132

CHAPTER 19 PROCESSING AND PRINTING 135
- A. Film Types and Processes 135
- B. One-hour Photo Finishing Plants 136
- C. Large Print Availability 136
- D. Specialized Images and Prints 136

CHAPTER 20 TV VIEWFINDER 139
- A. The 60 Hz Problem 140
- B. Antenna Problems 140
- C. Transmitter 140

APPENDICES

APPENDIX A LOW ALTITUDE RECONNAISSANCE SAMPLES 143
APPENDIX B FREQUENCY STATUS 148
APPENDIX C STARTER CART 149
APPENDIX D GLOSSARY 150
APPENDIX E ACRONYMS 152
APPENDIX F REFERENCES CITED AND SELECTED BIBLIOGRAPHY 154
APPENDIX G IMAGE MATHEMATICS, CHAPTER 12 IN METRICS 159

ILLUSTRATIONS, PHOTOGRAPHS, AND DRAWINGS

Figure 1.1 Changes in Resolution as a Function of Date Since 1944 3
Figure 1.2 Knight Smelter Operation 3
Figure 1.3 Oblique Photograph of Knight Smelter c. 1990 4
Figure 1.4 Vertical Photograph of Knight Smelter c. 1990 4
Figure 1.5 Camera Mount 5
Figure 1.6 Ultra-light Aircraft in Flight with Camera on Board 6
Figure 1.7 Woodard Mound 6
Figure 1.8 Nancy Patterson Site 7
Figure 1.9 Data Acquisition Design 8
Figure 1.10 Flight System Design 8
Figure 2.1 Pueblo Bonito 10
Figure 2.2 Pueblo Bonito Contour Plot Produced Using Figure 2.1 as Part of a Stereo Pair 11
Figure 2.3 Pueblo Bonito Cross-section of the Contour Plot 11
Figure 2.4 Ground and Film Coverage vs. Altitude 13
Figure 2.5 Minimum Allowable Blur vs. Film Format Size 14
Figure 3.1 Hand Launch of Butterfly Aircraft 16
Figure 3.2 Hand Launch of Telemaster Aircraft 17
Figure 3.3 Landing in a Cottonwood Tree 18
Figure 3.4 Net Landing 18
Figure 3.5 Basic Acquisition Costs (1988) 19
Figure 4.1 Fort Burgwin, New Mexico 22
Figure 5.1 Aircraft System Advantages 24
Figure 5.2 Weight and Balance Jig 24
Figure 5.3 Fuselage Jig 26
Figure 5.4 Dihedral Blocks 26
Figure 5.5 Typical Construction Schedule 27
Figure 5.6 Telemaster Parts Modification List 28
Figure 5.7 Spruce Side Stringers Modification 29
Figure 5.8 Photo of Camera Port from Outside the Fuselage 30
Figure 5.9 Surgical Tubing in Camera Port 31
Figure 5.10 Camera Port Cover 32
Figure 5.11 Wing on Balance Jig 33
Figure 6.1 Cutting Out Camera Mount 37
Figure 6.2 Mount Showing Rear Brace Covered 38
Figure 6.3 Camera in Mount with Sponge 38
Figure 6.4 Marking Center of Gravity (CG) on the Side of the Camera Mount 39

Figure 6.5 Vertical Line at the CG on the Side of the Camera Mount 40
Figure 6.6 CG Lines Meeting on the Side of the Camera Mount and the Side of the Fuselage at 6° 41
Figure 6.7 Wood Washers and Well Nuts 41
Figure 6.8 Wood Washers Glued in Place 42
Figure 6.9 Pulling Well Nuts Through Fuselage 42
Figure 6.10 Mounting Screw Through Grommet and Camera Mount into the Well Nut with the Mount in Place 43
Figure 6.11 Using a Mechanics Stethoscope and an Eraser 43
Figure 6.12 Drawing of Camera Mount and its Parts 44
Figure 7.1 Gluing of the Three 4" x 6" Pieces of Foam 48
Figure 7.2 Center-cut Hole in the Three-piece Foam 49
Figure 7.3 Clearance Cut for Penta-prism 49
Figure 7.4 Final Cut on 4" x 6" Foam 50
Figure 7.5 Taped Lens 51
Figure 7.6 Camera Mounted in Sponge with Trigger Circuit in Place 51
Figure 7.7 Full Camera and Mount 52
Figure 7.8 Picking Off a Foam Corner 53
Figure 7.9 Center of Gravity Check 54
Figure 7.10 Angle Mark for Oblique Camera Mount Foam 55
Figure 7.11 Glued Oblique Camera Sponge 55
Figure 7.12 Marking Lens Opening on the Camera Mount 56
Figure 7.13 Oblique Foam with Camera 56
Figure 7.14 Oblique Mount and Camera in Position 57
Figure 8.1 Fuselage Insides Prior to Assembly, Showing Carbon Fiber Strips 61
Figure 8.2 Fuselage After Assembly, Showing Carbon Fiber Strips Running Under the Bulkhead 61
Figure 8.3 Four Different Fuselages Built from Same Set of Calculations 62
Figure 8.4 Top and Under Views of Ricoh FF-90 Mounted in a UU Fuselage 64
Figure 8.5 Ricoh KR-10m in its Sponge Mount 65
Figure 8.6 New Ace Transmitter Console for LALSR 65
Figure 8.7 Photograph of the Test Target Area During the First Flight of the UU-2 Aircraft 66
Figure 8.8 Image of a Lava Dike at North End of Capitol Reef National Monument 67
Figure 8.9 USDA Imagery of Same Area as Figure 8.8 67
Figure 9.1 Trigger Circuit Diagram 70
Figure 9.2 Completed Trigger System 71
Figure 10.1 Flying Photo Lines 75
Figure 10.2 Eye Glasses and Corduroy Cap 76
Figure 10.3 45° Diagram 77
Figure 10.4 Grid View 77
Figure 10.5 Weights on Aircraft 78
Figure 10.6 Uncontrolled Mosaic of Nancy Patterson Site 79

Figure 10.7 Macrometeorological Conditions I 81
Figure 10.8 Macrometeorological Conditions II 81
Figure 10.9 Sample Checklists 83
Figure 10.10 Typical Flight Log, Log 20 84
Figure 11.1 Films Most Commonly Used with LALSR 86
Figure 11.2 LALSR Aircraft Parameters 88
Figure 11.3 Aerial Photograph Exposed at 78 foot Altitude with Telemaster Aircraft, 1/1000 Second Shutter Speed 89
Figure 11.4 Object-image Plot and Envelope 91
Figure 11.5 Aerial Photograph Exposed at 63 Feet Altitude with Butterfly Aircraft, 1/400 Second Shutter Speed 91
Figure 11.6 Aerial Photograph Exposed at 120 Feet Altitude with Butterfly92 Aircraft, 1/400 Second Shutter Speed 92
Figure 12.1 Image, Object, Focal Length, and Altitude Relationships 94
Figure 12.2 Mathematical Circle for Object, Scale, and Image 95
Figure 13.1 One by One-half Meter Cloth Control Panel Targets Set Out on the Ground 99
Figure 13.2 Low-Level Stereo Plotting Targets 100
Figure 13.3 Back Side of Plotting Targets 100
Figure 13.4 Four Back Side Plotting Targets Put Together for Higher Altitude LALSR Stereo Plotting 101
Figure 13.5 Elevated Ground Control Target Tower 101
Figure 13.6 Tower Leveling Attachment 101
Figure 13.7 Photograph of Elevated Tower in Use 103
Figure 14.1 USDA Aerial Photograph of Beaver Dam Wash Area 108
Figure 14.2 Topographic Map of Lytle Ranch Area 108
Figure 14.3 LALSR Photograph of Part of Lytle Ranch 109
Figure 14.4 Peeling the RC Layer From the Back of a Print 110
Figure 14.5 An Uncontrolled Mosaic 111
Figure 15.1 San Rafael Bridge 116
Figure 15.2 San Rafael Sink Hole 117
Figure 15.3 Strawberry Fish Hatchery 118
Figure 15.4 Pulsating Sprinkler Tests at Utah State University 119
Figure 15.5 Successive Coverage for Building Construction 120-121
Figure 16.1 Members of the First Class in Low Altitude Large-Scale Reconnaissance at Brigham Young University, Winter 1990 123
Figure 16.2 Members of the Second Class in Low Altitude Large-Scale Reconnaissance at Brigham Young University, Winter 1991 124
Figure 17.1 Ricoh FF-90 Modified 128
Figure 17.2 Ricoh FF-90 Super 128
Figure 17.3 Ricoh KR-30 129
Figure 17.4 Ricoh FF-7 129

Figure 18.1 Films that have been Used with LALSR 133
Figure 18.2 D-X Data Blocks Cut From Old Cassettes 134
Figure 20.1 Sony HVM-302 in Sponge Mount 139

APPENDIX PHOTOGRAPHS

Figure 1 Watpatki Archaeological Site 143
Figure 2 Heiser Archaeological Site 144
Figure 3 McIntyre Ranch 144
Figure 4 New Pleasant Grove Water Tank 145
Figure 5 Pecos National Monument 145
Figure 6 Las Vegas LDS Temple 146
Figure 7 Erosion Control Vandalism 146
Figure 8 Promontory Point 147

PART 1: INTRODUCTION AND BACKGROUND

HISTORY AND BACKGROUND

CHAPTER 1

The earliest aerial photographs were taken from balloons, but it was not until the development of the airplane and World War I that the use of aerial photographs and the potential of aerial photographic interpretation gain the interest of the scientific community. One of the pioneers in the field of non-military applications of aerial photography was O. G. S. Crawford, the first Archaeological Officer of the Ordnance Survey in Britain. From Royal Air Force photographs take of Stonehenge in 1921, he was able to identify the presence of buried features associated with the earthworks recorded by William Stukeley in 1723. During the same year he presented his first essay on applying the evidence from aerial photographs to archeological investigations of Celtic fields and their relationship to other earthworks in Wessex. He also developed the first systematic aerial photographic interpretation scheme for archeological sites: shadow-sites, soil-sites, and crop-sites. At the same time, Colonel G. A. Beazeley was conducting systematic aerial surveys in Mesopotamia (for additional information on the development of aerial photography refer to Leo Deuel's *Flights into Yesterday*, James Ebert's *Remote Sensing Applications in Archaeology*, D. N. Riley's *Air Photography and Archaeology*, and D. R. Wilson's *Air Photo Interpretation for Archaeologists*).

Reconnaissance and aerial photographic collection systems have ballooned in their capabilities since the early 1940s. In fact, in some cases, terms such as *scale*, *image interpretation keys*, *image motion*, and *detail producing capability* have all but disappeared from the reconnaissance vocabulary. Ask interpreters what the scale of the satellite imagery is and their answer will be, "Whatever scale you want." Further, they may wonder what scale has to do with the situation. As far as interpretation keys are concerned, they are now replaced with "field work and individual area examination with detailed notes." With regard to satellite imagery, we hear "there is no image motion." In detail-producing capability, some of today's imagery is measured in pixels and seconds of arc.

Need for such technology started in the 1940s when it was necessary to fly higher than the enemy could fly. High-quality, long-focal length lenses were manufactured to make objects on the earth appear closer. Optimum detail-producing capability was about 7 to 12 inches at the velocity and altitude reachable at that time. Even with today's new films, this capability has not changed significantly. Haze, that blue phenomenon caused by the molecular and particulate scattering of light, has caused and always will cause a problem with recording in some areas of the visible spectrum. Even today, the only way to eliminate the haze problem is to fly under it.

As image interpreters started in the reconnaissance industry, they were taught to use image interpretation keys. Today, we as a culture tend to be more visually literate, but there is also more for interpreters to see and understand besides a fixed set of military targets. One must almost become a specialist in the field one is photographing. Once again we are fast approaching the point at which these keys are again essential; and they must be developed by and for an individual discipline. Does it seem we have gone "full circle?"

The advent of the satellite brought coverage of larger areas of the earth's surface. The smallest detail the satellite will produce is the pixel. This size is either 10 or 30 meters square in size at the earth's surface depending on which type of satellite imagery is being used. This imagery is great for looking at plant communities, but not for looking at individual plants and their growth problems. What about the detail within the pixel?

Our "balloon" seems to have some flat spots on it along with bulges. Low altitude, large-scale reconnaissance, along with other image recording approaches yet to be developed, can be helpful in smoothing it out.

What good is satellite imagery at a scale of 1:400 that will only put 25 pixels on a 12 inch-square photograph? Have we regressed to the point where we must develop our own image-interpretation keys, because none are available for our respective discipline? If so, we had better take and share accurate notes. Can we now say that image motion is equal to the product of the scan rate and the scan angle? If not, then what good is the imagery? Let us use each type of imagery where it will be most beneficial: the satellite for large area coverage, NAP imagery for mapping and midrange coverage, and LALSR imagery for detailed high resolution coverage.

SCALE, APPARENT SCALE, OR
DETAIL-PRODUCING CAPABILITY?

Earth Surface Resolution

Resolution in inches	Time	Sensor
7.40	1944	F-5 (P-38)
5.70	1962	U-2
5.30	1987	NAP
389.00	1988	SPOT
0.52	1989	LALSR
0.21	1989	LALSR

Figure 1.1
Changes in Resolution as a Function of Date Since 1944

At a time when "higher and more sophisticated" seems to be the way of reconnaissance technology, there is still a need for highly detailed large-scale photographs of small areas. Brigham Young University has needed this type of imagery for archaeology excavations since 1971. Early efforts to achieve this have included use of cherry pickers, irrigation tube tripods, and compass-aligned balloons for camera platforms. These procedures were abandoned because of the elevation limitations of cherry pickers and irrigation tube tripods, and because the tethered balloons were too subject to wind and weather problems.

In the fall of 1972, 1:1000 scale imagery of the abandoned Knight Smelter in southern Utah County was requested by both the Departments of Geography and Anthropology. A tethered balloon with a compass-aligned camera mount (Figure 1.2) was used to give directionally aligned photographs. The winds against the side and front of the balloon blew it back into the ground because of the pivot arm effect of the tether line. As a result, this project was only

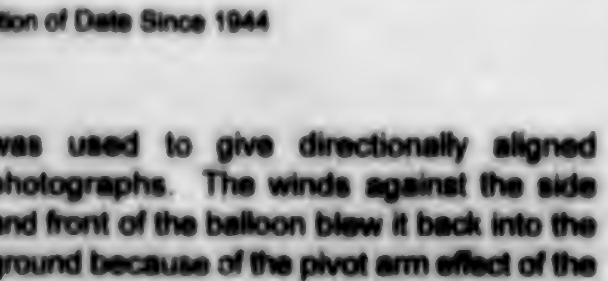

Figure 1.2
Knight Smelter Operation

marginally successful. During September of 1990 when this project was repeated using low altitude, large-scale reconnaissance (LALSR) aircraft, the results were much more successful (Figures 1.3 and 1.4).

Figure 1.3
Oblique Photograph of Knight Smelter c. 1990

Figure 1.4
Vertical Photograph of Knight Smelter c. 1990

Figure 1.5
Camera Mount

During the summer of 1980, Brigham Young University requested large-scale photographs of the Woodard Mound and Old Goshen Town archaeological digs. As a result, we designed a differential density sponge and wood camera mount (Figure 1.5), then built and tested it with an ultralight aircraft (Figure 1.6). The system's weight limitations for the ultralight aircraft camera pod were set at 6.1 kilograms. Excellent results were obtained using this mount. The final system weight was only 5.4 kg, including mount, camera gear, and intervalometer. This weight addition is within the safe flight envelope of most ultralight aircraft. The results of the first few flights with this mount were excellent, the costs were low, and the results visually sensational (Figure 1.7). The ultralight flew over both sites at a ground speed of 12 mph (into a 12 mph headwind) and at an altitude of 400 feet.

During the summer of 1984, we made flights over the Nancy Patterson archaeological ruin in Montezuma Canyon in southeastern Utah (Figure 1.8) using this same camera mount. Results were excellent and an uncontrolled mosaic was created from the imagery. Again, costs were minimal.

Changes in the interpretation of ultralight aircraft usage by the Federal Aviation Agency (FAA) between 1980 and 1983 prevented people from using ultralight aircraft for reconnaissance on a regular basis. So in 1984 when the decision to develop a low altitude, large-scale reconnaissance program was made, use of a remote piloted vehicle (RPV) program was also discussed as a contingency. During 1985 and 1986 as it became even more obvious that with changes in FAA regulation interpretation and with the additional risk management constraints, the RPV program would have to become the Brigham Young University approach to LALSR.

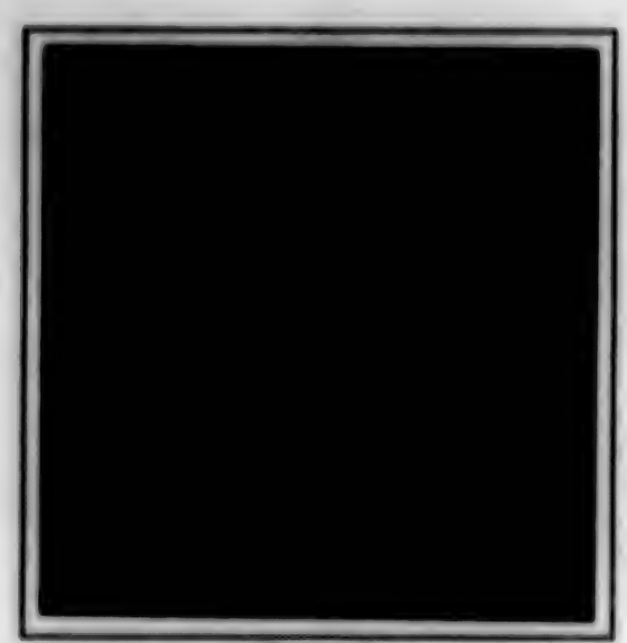

Figure 1.6
Ultra-light Aircraft in Flight with Camera on Board

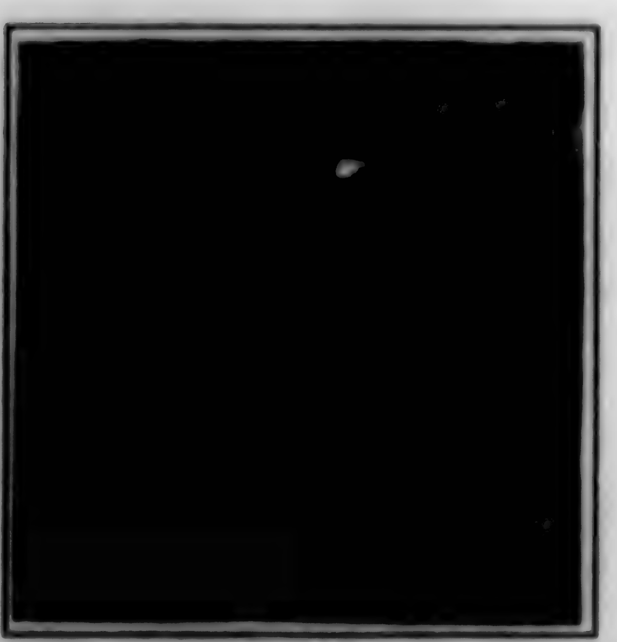

Figure 1.7
Woodard Mound

Figure 1.8
Nancy Patterson Site

At this point, we evaluated the past and determined that thus far we had learned the following:

1. Low-altitude reconnaissance eliminates haze problems often caused by temperature inversions.
2. Rotary-wing aircraft are not cost-effective for most university research projects; they have vibration problems, and at low altitudes they create surface problems such as flattened grass, dust, and surface destruction.
3. Image motion or blur is held to a minimum with minimum velocity of the reconnaissance vehicle.
4. Vibration of the recording device (camera) is kept at a minimum by use of multiple-density sponge and wood mounts.
5. Sun angle at low altitudes, even more than other types of reconnaissance, can be used to enhance detail and surface relief.

When the large-scale imagery program started in 1971, the goal was to obtain large-scale, motion-free, high-quality images. A basic set of criteria was now established in 1985, based on our experience, the desired results, and the economic constraints. The economic constraints were low risk, low impact, and low cost, both in the form of image acquisition and system maintenance. These criteria were further classified into data-acquisition design (Figure 1.9) and flight system design (Figure 1.10).

Note that the velocity and vibration criteria are mentioned in both data acquisition and Flight system design criteria. Velocity and vibration affect image quality. They also affect the ability of an aircraft to fly since aircraft will not fly below stall speed. Those characteristics required of an aircraft for slow flight also affect vibration.

A. Large Scale
B. High quality
C. Low altitude
D. Low velocity
E. Low vibration
F. Low risk
G. Low impact

Figure 1.9
Data Acquisition Design

A. Low velocity
B. Small takeoff and landing space
C. Portability
D. Low cost
E. Low vibration

Figure 1.10
Flight System Design

DESIGN OF THE DATA ACQUISITION SYSTEM

CHAPTER 2

Large-scale imagery is often defined in terms of prevailing environmental conditions and also through the eyes of the individual needing the imagery. Therefore the first item is to define the scale of imagery for LALSR. As recorded on film, LALSR varies in scale between 1:6000 and 1:400. With the finished print, this scale will vary from between 1:1700 and 1:20. *Scale* is the ratio between image size and object size. This means that for a scale of 1:100, one inch of length on the photograph equals 100 inches of length of the original target area. Therefore, optimal LALSR film imagery is here defined as having a scale of between 1:6000 and 1:400, with capabilities of twenty-diameter (20x) enlargement. These numbers will be further explained in detail in the sections on image-motion problems and image math. They do represent the capabilities and limitations of the LALSR system.

A higher quality original image provides greater capabilities for large-scale reproduction. Images exposed at an altitude of 78 feet with existing equipment have produced twenty-diameter enlargements, providing a 1:25 scale (Figure 11.3). Today, film and 35mm cameras that produce this type of imagery are readily available. This scale requirement places the aircraft two orders of magnitude closer to the ground (i.e., 100 vs. 10,000 feet) than when conventional large-scale photographs are taken. At this lower altitude, image blur due to the speed of a conventional aircraft is a major problem. The area visualization comparison is coverage of a single-unit dwelling, where as previous normal large-scale coverage is village or large-subdivision size.

Although the cameras currently in use have not been calibrated, they have also provided images capable of producing one-third foot contour intervals using an H. Del Foster (HDF) plotter (Figures 2.1, 2.2, and 2.3). With proper surveying techniques, proper programming with the computer plotter, and a qualified operator, it is possible to achieve good contour plotted results.

At this point it should be obvious that large-scale imagery is dependent on high quality images, which in turn are dependent on low altitude, low velocity, and low vibration. Three criteria are interdependent and can become a vicious circle when a research program on any one of the criteria is conducted. A critical examination of each of the criteria is needed individually to determine where the constraints are.

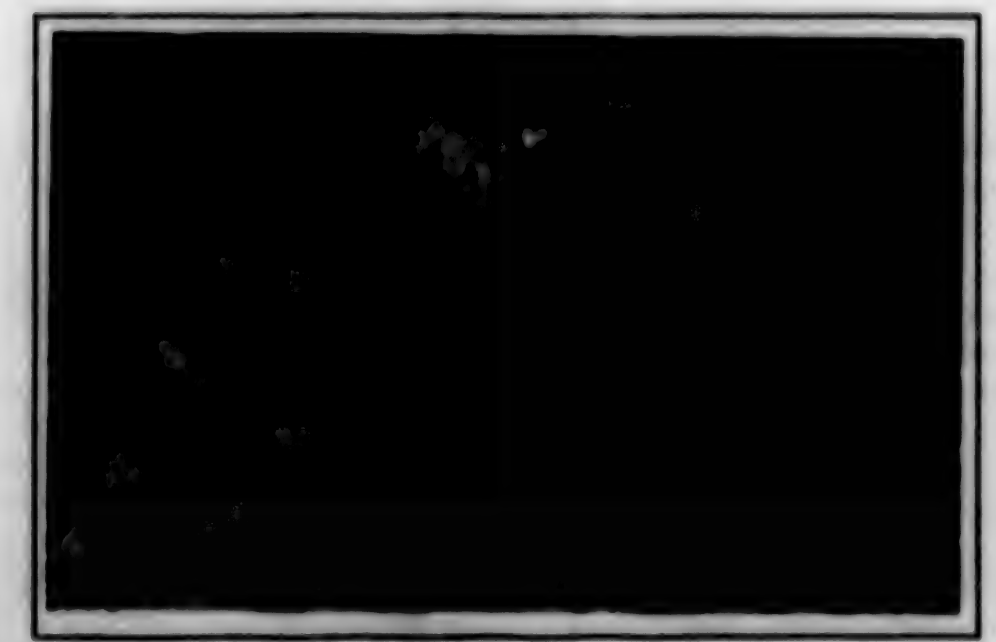

Figure 2.1
Pueblo Bonito

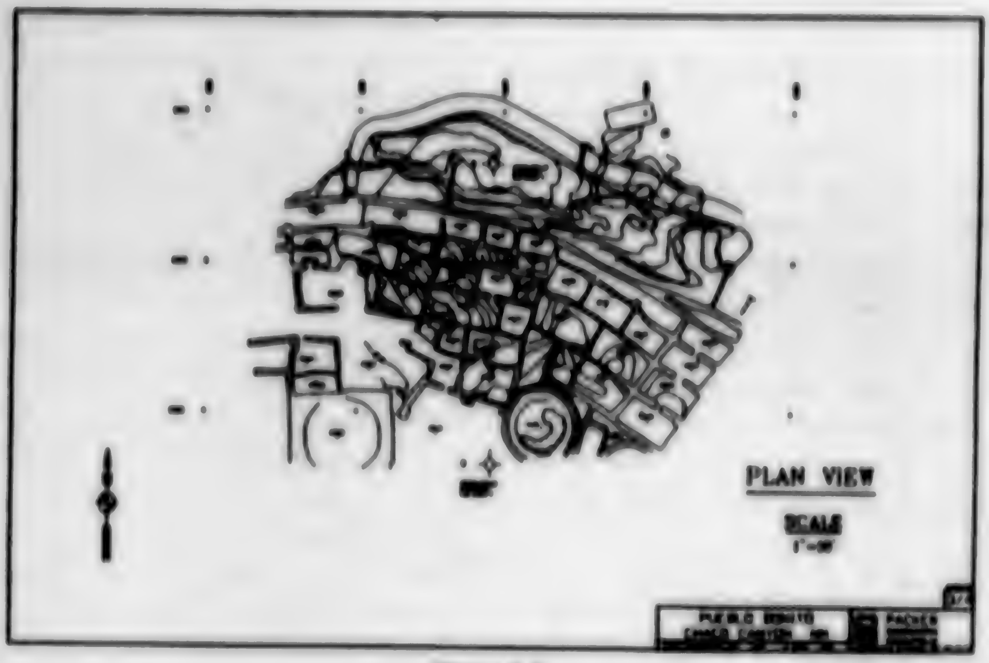

Figure 2.2
Pueblo Bonito
Contour Plot Produced Using Figure 2.1 as Part of a Stereo Pair

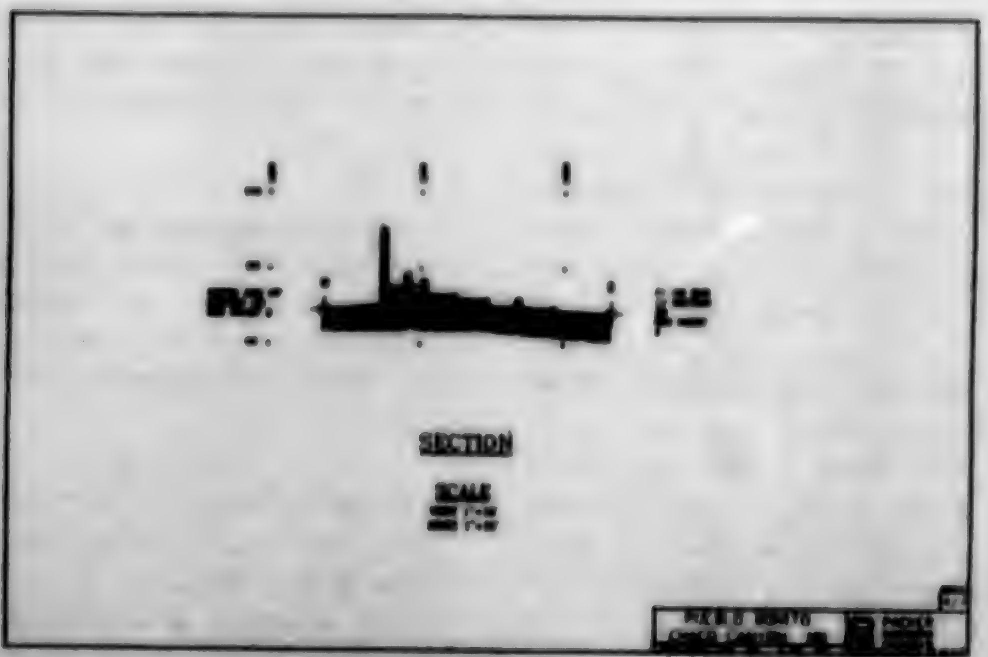

Figure 2.3
Pueblo Bonito
Cross Section of the Contour Plot

A. Large Scale

There are a number of ways to obtain large-scale aerial imagery: telephoto lenses, helicopters, large projection prints, balloons, and low, slow-moving RPV aircraft. Each method has its drawbacks. Telephoto lenses have image-motion problems, and these, along with atmospheric haze, degrade the imagery. Helicopters have the vibration and image-destruction problems previously mentioned. Large projection prints have practical film resolution limitations. Balloons have gas transfer and wind problems. Low, slow-moving RPV aircraft also have their drawbacks, not the least of which is altitude measurement and pilot training; however, for the funding involved, they are perhaps the most economical and produce more detailed imagery than the other methods. Further, flying at low altitude, especially in the Southwestern United States, reduces the amount of haze that may obstruct the view of an object. In Utah, most temperature inversion layers are about 600 feet above the ground. Flying below 600 feet where there is essentially no haze makes it possible to use films that are not rated with aerial exposure indexes. Using an incident light meter to determine exposure before flight produces excellent exposed images with most 35mm films. In fact, because of the lower haze problem, standard film speeds can be used rather than the aerial exposure indexes used with higher altitude aerial photography.

A larger number of film emulsion types can be used when standard film speeds are used, simply because more film is available with this type of data. Further, more films are available in 35mm format than any other size. Also because of the economics involved, newer and better film types are first being tested and marketed in 35mm format, giving the additional opportunity of testing them sooner.

B. High Quality

High-quality images are a product of good optics, sharp film, and a steady camera. Standards have been set on the basis of acceptable blur, given as 0.09 mm on a standard 9x9 aerial image (Figure 2.5). This means that a 35mm image must only have 0.01 mm or less blur to produce a 9x9 print of sharpness equal to that of a 9x9 original image. In terms of motion, with a 50mm lens at 1/500 sec. shutter speed, the forward velocity of an aircraft cannot exceed 30 feet per second. As previously mentioned, sharper images are also possible with haze reduction. The low altitude for which the RPV is designed effectively eliminates the haze problem.

Technological advances in optics over the last thirty years have been phenomenal. Excellent lenses are available even for inexpensive cameras. Ninety to 100 lines per millimeter resolution are common on these cameras.

Like optics, the quality of films has improved over time; films are much sharper now than even ten years ago. Thin emulsions, "T-grain" coatings, thinner base stock, better anti-halation protection, and better spectral sensitivity control have all contributed to increased film sharpness. The photo industry has produced excellent optical products and film; these can almost be considered as fixed constants in high-quality imagery.

The steady camera is the variable factor, because unlike a tripod an aircraft never stops moving. The camera photographs whatever is in front of it when the shutter is open, whether the camera is moving or not. If it is moving, the image will blur, and that blur will be proportional to the time the shutter is open. The shorter the shutter speed, the less the blur. Present technology limits this shutter speed to about 1/400 of a second with lightweight 35mm cameras and 1/1000 of a second with the heavier single lens reflex (SLR) cameras (Note: It is realized that some manufacturers claim faster shutter speeds, but let a shutter speed tester be the guide to real shutter speed after the first forty rolls of film.). With the shutter speed somewhat fixed, the variables remaining in image quality are altitude (distance from the object), aircraft velocity, and vibration.

C. Low Altitude

Although the ground-level distance covered by an aircraft may be no different, the distance the image moves on the film is twice as great for each one-third distance decrease in altitude (Figure 2.4). This is not a serious situation until the distance moved on the film exceeds the resolution of the film and camera system. At this point, the maximum capability of the reconnaissance system has been reached. With all other data acquisition points fixed, only velocity and vibration may change. Devices designed to reduce image motion blur are available, but they are both heavy and expensive. In fact, their weight exceeds that of the most used LALSR aircraft and their equipment. Also, for most low-budget operations, such as archaeological digs, the cost of image motion compensation equipment is prohibitive. The best solution is slow camera velocity over the study area.

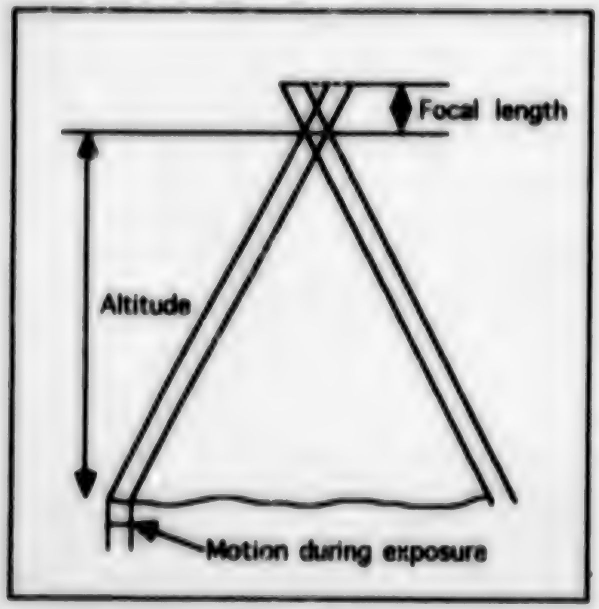

Figure 2.4
Ground and Film Coverage vs. Altitude

D. Low Velocity

Low velocity at low altitude is necessary to prevent excessive blur, but the velocity of an aircraft can be slowed down only so far before the aircraft will stall and fall. Slow flight is not good for pilot safety and heavy payload. The ideal aircraft for LALSR is one with minimum wing loading or a large wing area with an airfoil that has low speed stall characteristics. The use of a pilotless vehicle eliminates the weight of crew members and safety equipment. It also allows for additional design variation in which only the prime mission of the aircraft need be considered. Then the problem to overcome will be the vibration caused by aerodynamics and the power plant.

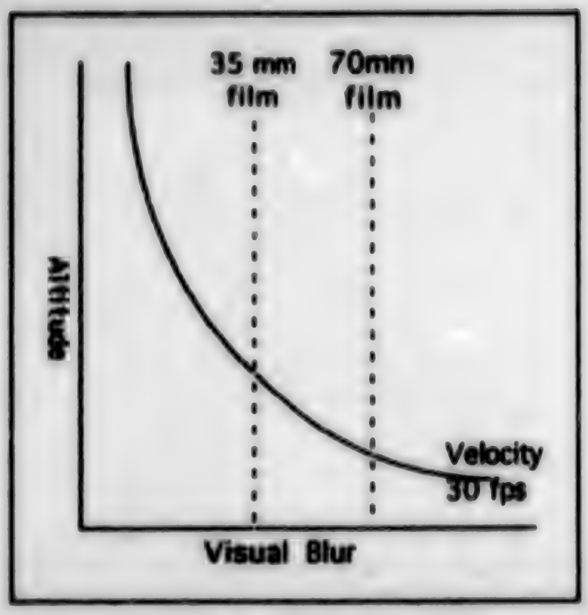

Figure 2.5
Minimum Allowable Blur vs. Film Format Size

E. Low Vibration

Aerodynamic vibration is a problem associated with an object's motion through the air. Vibration increases as the aircraft moves faster. It should be safe to say, therefore, that the slower LALSR aircraft moves, the less problem there is with aerodynamic vibration.

The power plant causes most of the vibration, and this can be transmitted to the camera through the airframe via several routes. Metal rods (especially those running parallel to the fuselage length), the airframe itself, the camera mount, and mechanical devices used to trigger the camera may all contribute to camera vibration. Wing saddle foam and rubber band wing mounting tend to reduce vibration resonance in the fuselage.

Properly designed camera mounts can reduce vibration tremendously. Use of different sponge densities to absorb vibrations of different frequencies seems to work best. The power plant cyclic rate is between 75 and 150 cycles per second (4500 to 9000 rpm). If the camera is properly suspended in sponges (polyurethane) of densities 0.5, 0.6, 0.75, and 1.1 pounds per cubic foot, and the sponges, in turn are placed in low-density wood restraining cases, the powerplant vibration is reduced to near zero at the camera. Obviously, proper sponge placement is critical. High frequency vibrations are best absorbed by wood and high-density sponge; low frequencies are best absorbed by low-density sponge. Because all sponge passes some vibration, a low-density sponge is used on one side of the camera and a higher density sponge on the opposite side. The mounts described later were designed for photographic operation at power plant speeds between 4,500 and 9,000 rpm.

We tested both two- and four-cycle engines; my preference became one of cost and low weight (2-cycle) versus lower amplitude of the vibration (4-cycle). Over a period of time and usage, lower amplitude of vibration seems to be the preferred system.

SYSTEM DESIGN

CHAPTER 3

With any design project, serendipity seems to play a role. These discoveries come when you reason, "As long as you're doing this, have you thought about ...?" and there are those things that just happen. This is what happened to some of the system design criteria (Figure 1.10). As the system developed, additional constraints were inevitably placed upon the design criteria--some to increase capabilities, and others to simplify the system. Opportunities to solve small launch and landing spaces came along during system development.

A. Low Velocity

A new kind of "old" flight parameter had to be developed for a slow-flying, fixed wing aircraft with a camera payload. After eighty years of trying to make aircraft fly faster and higher, there was a need to fly slower and lower. This type of flight requires maximum stability and lift at minimum velocity. Flight attitude approaches a power-on stall while trying to maintain level wings. Meteorological ground effects such as dust devils and ground surface color changes can be devastating when their velocity exceeds that of the aircraft, so stability is essential for quick recovery.

The following parameters became necessary as design considerations for this type of aircraft:

1. Aspect ratio (wing efficiency).
2. Airfoil (lift).
3. Aerodynamic drag (velocity).
4. Wing dihedral angles (stability).

A few aerodynamic calculations were made, and a large wing area with a thick, flat-bottom airfoil and high aspect ratio became the object of a search to find an "off-the-shelf" model kit that would carry the designated load at thirty feet per second (20 mph). Two kits fit these criteria, and the aircraft were purchased, built, and flown to demonstrate their capabilities. These two aircraft have been used since then for reconnaissance, demonstration, modification, testing, and advanced testing of new camera equipment. The two model aircraft are: 1) Butterfly, marketed by Dynaflite, and 2) Senior Telemaster, marketed by Hobby Lobby International. Both aircraft performed well once the vibration problems were solved. The only modifications required were additional external drag to the Butterfly for proper performance in the desired speed range, and additional fuselage width for the camera with the Senior Telemaster. The external drag added to the Butterfly was removed once the camera mount was added. Both aircraft have tested satisfactorily in the 20 mph speed range from a ground level of 4500 feet above sea level (ASL). LALSR operations have been flown from the highest ground level of 9200 feet ASL to the lowest ground level of 60 feet ASL.

B. Small Take-off and Landing Space

Many involved in field research and survey do not have the luxury of having a flying field for takeoffs and landings. This is especially true at archaeology sites. With helicopters and ultra-lights, there is the inevitable clearing of brush from the sides of the road, etc. Because the LALSR RPV is small, light, and slow, it can be hand launched with essentially a zero-length runway. Hand launching is relatively simple, especially with the Butterfly aircraft--so much so that all camera flights are now hand launched (Figures 3.1 and 3.2). This type of launch also tends to keep the camera lens cleaner. A favored approach to hand launching has been to finish the checklist and set the power plant at idle, then pick up the aircraft and face it into the wind, holding it straight and level. Have someone hand you the radio, advance the throttle slowly, and when full power stabilizes, run forward with the aircraft until it rises out of your hand. It is more difficult than it sounds, but it becomes quite easy with practice.

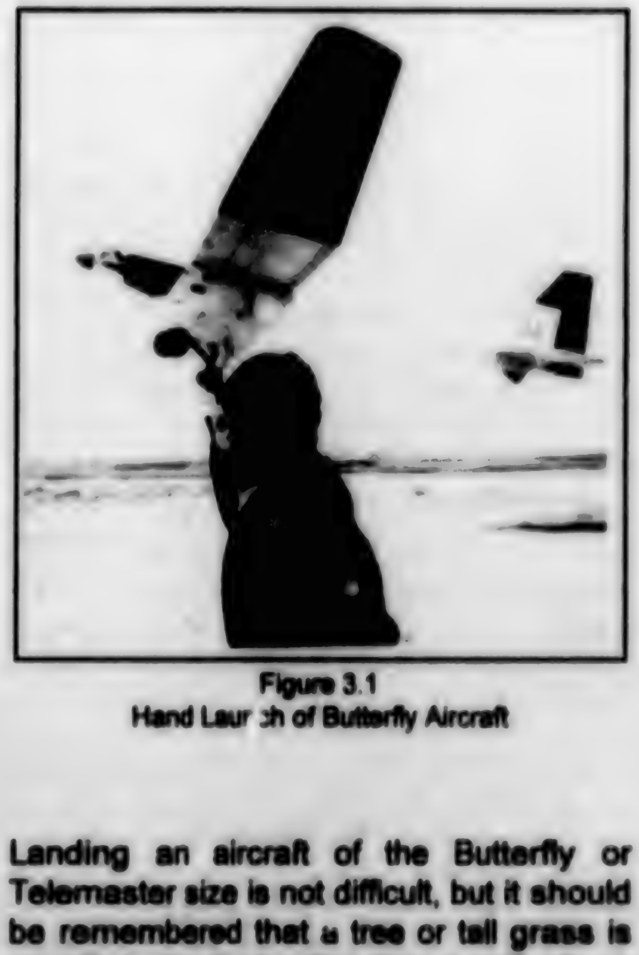

Figure 3.1
Hand Launch of Butterfly Aircraft

Landing an aircraft of the Butterfly or Telemaster size is not difficult, but it should be remembered that a tree or tall grass is usually better for landing than a rock pile or a rough road (Figure 3.3). Safe landings have been accomplished in nets, trees, sagebrush, and grass. Sometimes straight rough roads are more hazardous than sage brush. Damage during a tree landing is usually minimal if it is preplanned. Net landings are also possible when weather and wind conditions permit (Figure 3.4). With care, little or no damage will occur on most landings. Even some tree landings have permitted second launches within minutes, with new film in the camera to cover other targets in the immediate area. Most of all, for your own safety, do not try to catch that five-pound cannon ball with a meat slicer on the front of it!

C. Portability

Because of their comparatively small size and light weight, both types of LALSR aircraft can be transported, with support equipment, in a small station wagon or mini-van. This increases their availability and cost effectiveness. In small station wagons and vans, both aircraft have traveled extensively throughout the Southwest (Arizona, California, Colorado, Nevada, New Mexico, and Utah). Further, the larger of the two aircraft has been flown round-trip between Provo, Utah, and Edwardsville, Illinois, as was the smaller aircraft between Provo and Augusta, Georgia. All support equipment except fuel and starter battery were included in the transport. Careful planning and a cooperative case manufacturer made it possible to transport the system as baggage on commercial airplanes, including overseas to India.

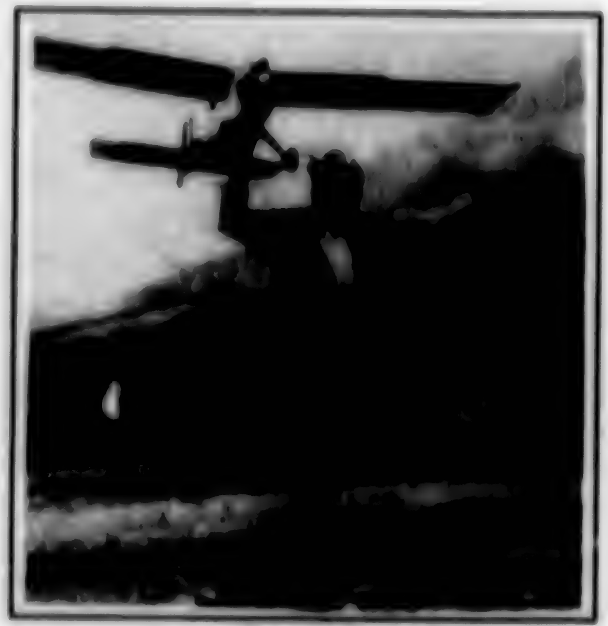

Figure 3.2
Hand Launch of Telemaster Aircraft

Figure 3.3
Landing in a Cottonwood Tree

Figure 3.4
Net Landing

D. Low Cost

Low-budget constraints started the development of LALSR. After quality, cost ranks second on the priority list in most low-budget programs. To get into LALSR, one must buy the needed materials at a local hobby shop, photographic store, and electronics supply house. One can assemble these materials oneself, or have someone else do the construction work. The basic construction cost for the successfully tested RPVs is minimal (Figure 3.5) in comparison to other types of reconnaissance vehicles. Construction time depends on an individual's background and the amount of time he or she has to spend on the project. Periods of inclement weather seem to be best time for building, maintaining and repairing. Most repair work involves patching up the aircraft covering with Monocote–the Mylar material with which it was originally covered.

Operational costs average approximately $10 per flight, plus film and operator crew time. Replacement costs for damaged o destroyed vehicles is the same as the kit cost listed below, since the control equipment and cameras are usually not damaged and can be transferred to the new vehicle. Therefore, when airframe termination becomes unavoidable because of the site environment, the SRPV still proves to be cost effective. The original Butterfly aircraft that was built to test LALSR ideas and concepts is still in flying condition, with over 250 flights on the airframe. The fuselage was replaced after those 250 flights at a cost of $25.00. The wings were re-covered after 172 flights for the cost of the Monocote.

Slow-flight RPV operator training is inexpensive and relatively simple. At archaeological and other field sites, someone who has other duties to perform during the remainder of the day or week can be trained to fly. This operator approach has also been used in similar situations by surveyors and agricultural and animal researchers. In terms of cost, this type of operation is probably the least expensive of any type of airborne reconnaissance.

	Butterfly II	Telemaster
Kit Cost:	$ 64.00	$159.00
Modification and Finishing:	33.00	62.00
Engine:	35.00	150.00
Radio:	200.00	200.00
Camera:	250.00	340.00
Interface:	30.00	30.00
TOTAL	$612.00	$941.00

Figure 3.5
Basic Acquisition Costs (1988)

E. Low Vibration

Vibration problems are so intertwined that separating them between data acquisition design and system design becomes redundant. Rereading the first low vibration section would be more valuable than would the separation of that section into two parts.

F. Low Risk

Often because of limited space, LALSR equipment requires rapid, radical maneuvering. In these situations, not having a person on board during flight prevents pilot injury. Also, in many of these situations, a full-sized aircraft cannot operate either. Smaller and lighter LALSR equipment also reduces the potential of damage to the environment. Operational flights vary from 8 to 20 minutes for 20 to 30 exposures, greatly reducing flying time. Weather requirements for LALSR flying allow flying only under optimum conditions, further reducing problems. Because of the size and weight involved, it is recommended that transportation of the equipment be totally enclosed, adding to its protection. Yet even a total loss of a system would not be expensive--especially when compared to a full-sized aircraft and its associated reconnaissance equipment.

G. Low Impact

For most RPV flights, no changes have to be made in the environment such as trimming roadsides and building runways for operations. Fuel is in most cases is a renewable resource and is not fossil-related. Normal fuel consumption does not exceed six ounces for the longest of flights. A fully loaded Butterfly consumes less than six ounces in forty minutes. One advantage of this system, as expressed by the National Park Service, is that the RPV can be brought on site, fly, expose photographs, land, and leave the area with no signs of having been there.

SUMMARY

CHAPTER 4

LALSR fills a gap in reconnaissance: it has capabilities of producing high-quality, large-scale photographs by photographing at altitudes where haze is not a problem, where sun angle can be better used to enhance imagery, and at a velocity slow enough to reduce blur. Vibration can be controlled by using specially designed, variable-density sponge camera mounts. The risk involved in LALSR aircraft is less than with full-size aircraft because of the velocity and mass differentials involved at low altitude. Pilot (operator) safety is also greater when on-board operation is not required. Environmental impact is minimal in terms of destruction, usage, and pollution.

Ninety percent of the imagery displayed in this book was originally exposed in color (both negative and transparency); there is always some loss in the printing process, so you will not be able to see all the detail described. For example, hose couplings on green hoses in green grass are visible at 400-feet altitude (Figure 4.1), and chaining pins and their shadows on gray sand are visible from 78-feet altitude (Figure 11.3) on the original film. With proper use and planning, this system is capable of producing good quality imagery at a scale between 1:6000 and 1:400, with high-quality prints of a scale between 1:1700 and 1:20.

Now that we have discussed the background, research, and capabilities, let's look at the practicality of this system. The remainder of this book is divided into three areas of study: (1) aircraft construction and maintenance techniques, (2) practical reconnaissance and image interpretation considerations, and (3) photographic (cameras, film, and processing) considerations. This format allows those with expertise in any area to more easily refer to the other sections for information they need.

Extensive use is made of references to other publications in this text. Carl Strandberg's *Aerial Discovery Manual*, Don Dewey's *RCM's Flight Training Course*, and Jule Caylor's *Film, Camera, and Mission Considerations to Reduce Image Motion Effects on Photos* are considered essential references for the serious researcher. Any recommended film data book would be out of date within a year because of the rapid changes taking place in the film manufacturing industry. Even the camera industry is rapidly changing.

Figure 4.1
Fort Burgwin, New Mexico
(In the Color Photograph, Hose Couplings on Green Hose in Green Grass Are Visible)

PART 2: AIRCRAFT CONSTRUCTION AND MAINTENANCE

CONSTRUCTION TECHNIQUES

CHAPTER 5

The decision whether to use the Butterfly or the Telemaster is up to the individual, and his or her needs. The user's experience with building and flying should also be considered. If you have had no experience in building or flying, then it may be advisable to start with the Butterfly, because it is easier to build and to fly slowly. It is also an excellent trainer for learning the basics of flying. The initial investment and maintenance is also less than with the Telemaster. The camera used in the Telemaster is heavier and better. If you have had some flying experience, and will be working with good landing facilities, then building the Telemaster may be to your advantage (Figure 5.1).

If you decide to build the Butterfly aircraft, you will need the following list of items to complete your project:

1	Dynaflite Butterfly kit
1	Five-Channel model aircraft radio control set (Appendix B)
1	0.15 or 0.20 model aircraft engine
1	Glo-plug
1	Prop and spinner to match engine
1	Radial engine mount to fit the engine
4	4-40 x 3/4" screws with T-nuts
1	4 ounce slant tank
2	2-1/2" wheels
4	5/32" wheel collars
2	Rolls Monocote covering.

BUTTERFLY AIRCRAFT
System Benefits

a. Simplicity
b. Maneuverability
c. Portability (size)
d. Camera weight
e. Cost
f. Easy hand launch
g. Turn around time
h. Smaller landing area

TELEMASTER AIRCRAFT
System Benefits

a. Camera quality
b. Shutter speed control
c. Additional film usage (slower ISO)
d. Oblique capability
e. Viewfinder capability
f. Ground take-off capability
g. Four-cycle engine capability

Figure 5.1
Aircraft System Advantages

If you decide to build the **Telemaster aircraft**, you will need the following items:

1 Hobby Lobby Senior Telemaster Kit
1 Senior Telemaster accessory pack
1 Five-channel model aircraft radio control set (Appendix B)
1 0.60 four-cycle or 0.45 two-cycle model aircraft engine
1 Glo-plug to fit engine
1 Prop to fit engine
4 6-32 x 1/2" screws with T-nuts
1 The items listed in Figure 5.6.

A. Work Area

The work area should have a work table or bench, 110 volt AC electricity, and good lighting. The area should be used only for construction, so that work that has been glued can be left out overnight to dry. Other necessary tools are listed below. This list came from notes we kept during the construction of a fourth Butterfly. Those items marked with an asterisk (*) were not used during the construction of the first Butterfly or the first Telemaster, but were found to be valuable. Many unmarked items are household items, or items available at the local hardware store. The preferred approach to sanding blocks has been to apply a coat of rubber cement to one side of the sanding block and another coat to the back of the sandpaper. When both are dry, the two glue surfaces are brought into contact with each other. After the sandpaper is worn out, it is peeled off and new rubber cement applied to the block and the new sandpaper.

B. Tools

1 2' x 4' sheet of Cellotex
1 Cutting board (Masonite scrap over 4" x 10")
2 1/4" x 3" x 7" wood sanding blocks
1 #11 X-acto knife handle*
1 Razor saw*
1 Utility knife
1 Small wood plane*
1 Pair scissors
1 1/4" hand paper punch
2 Pair miscellaneous pliers

1	Pair dikes
1	Prop and glo-plug wrench
2	Screwdrivers (small)
1	Pin vise with a 1/16" drill*
1	1/8" drill
1	3/16" drill
1	1/4" drill
1	5/16" drill
6	2" C-clamps* and/or 1 dozen clothes pins
1	Solder iron (small)
1	Dremel tool*
1	Monocote sealing iron
1	Heat gun*
1	Small vise*
1	12" ruler
1	6" plastic ruler
2	Small plastic triangles, any 90° configuration
1	Center of gravity and balance jig (Figure 5.2)*
1	Fuselage jig (Figure 5.3)*
2	2" x 3" x 4" wood blocks (Figure 5.4).

The fuselage jig (described Chapter 6, pages 30-31 in the *RCM Flight Training Course)* is not essential to build a good fuselage, and it was not used on either original aircraft, but it saves considerable time (Figure 5.3). Your local model club may have one you can borrow or rent .

The dihedral blocks (Figure 5.4) are two identical blocks of scrap wood that help brace the wings of the aircraft during the gluing process, during which dihedral angles are critical. They are slightly sticky (coated with thinned rubber cement); the dimensions are not critical so long as the two blocks are identical.

The weight and balance jig (Figures 5.2 and 5.11) is made from two 2x4's 16 inches long, two 1/2-inch diameter dowels 13 inches long, and two 1/2-inch rubber tips. It is sometimes referred to as a CG (center of gravity) jig. This jig is not essential, but it is very helpful. Its use will be discussed later in this section.

Figure 5.2
Weight and Balance Jig

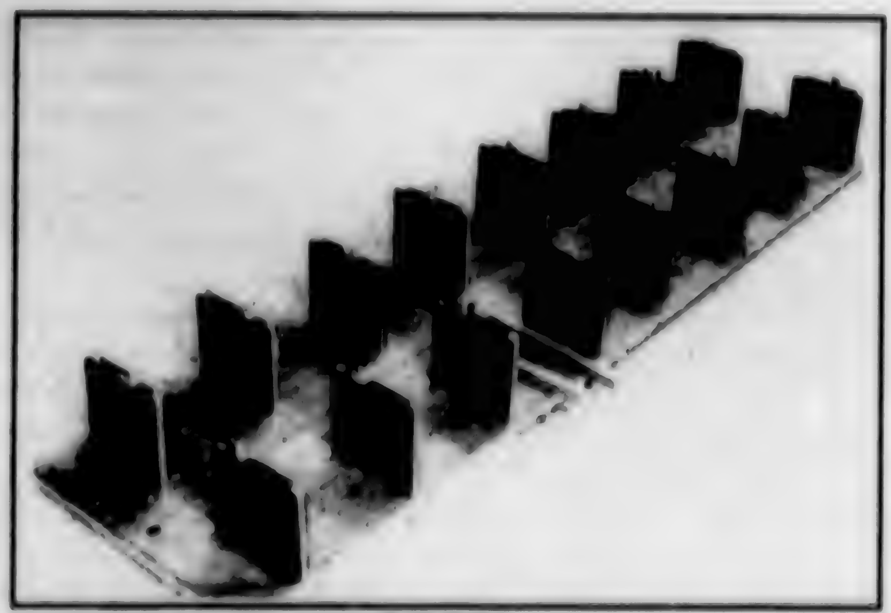

Figure 5.3
Fuselage Jig

Figure 5.4
Dihedral Blocks

There are also construction supplies which, unlike tools, are needed for building aircraft and are either used up or worn out during the construction of the aircraft. These are listed below--including the glue and adhesives.

C. Construction Supplies

4	Single-edge razor blades
1	Box #11 X-acto knife blades*
1	Package large T-pins (100 1-1/4" long)
1	Roll of wax paper
1	Roll 3/4" masking tape
1	Dozen 2" x 2" cardboard squares (for epoxy)*
1	Sheet #120 sandpaper
1	Sheet #200 sandpaper
1	Box small round toothpicks
1	Fine felt-tipped marker
½	Pint Pratt & Lambert Varmour varnish
1	Pint mineral spirits
1	Small sponge brush
1	Notebook for notes
6	Ounces Titebond glue
2	Ounces 5-minute epoxy
1	Small bottle pink Zap
1	Small bottle green Zap*
1	Bottle rubber cement.

If you have had no experience with model construction, it would be helpful to study the first few chapters of the *RCM Flight Training Course*. Keep notes on all you do. This will help prevent problems. You may also ask for help from your local hobby shop.

D. Butterfly Construction

Next, set up a work schedule and stick with it step-by-step. Working in two-hour blocks seems to be most beneficial. If you are building a Butterfly, for example, the following sequence is a good one.

Construction Steps

1. Layout, reading instructions
2. Tail parts construction
3. Wing construction
4. Wing construction
5. Wing construction
6. Center spar gluing
7. Wing construction
8. Sanding
9. Hinging and control horns
10. Fuselage construction
11. Fuselage construction
12. Fuselage construction
13. Trigger construction
14. Camera mount construction
15. Accessory installation
16. Varnish and cover
17. Varnish and cover
18. Varnish and cover
19. Finish construction
20. Finish construction
21. Radio check, controls, and taxi
22. Flight test

Figure 5.5
Typical Construction Schedule

Part No.	Pieces	Dimensions (in.)	Material	Name
1	1	5-7/8x4-3/4x3/16	Balsa	Bulkhead 3
2	1	7-1/2x4-3/4x1/4	Balsa	Bulkhead 2
3	1	4-11/16x4-1/2x1/4	Plywood	Bulkhead 1
4	1	5-1/4x3-1/4x1/4	Plywood	Landing gear mount
5	2	6-3/4x1/4 dia.	Birch	Hold down dowel
6	1	9-1/2x5-1/8x3/8	Balsa	Fuel tank hatch
7	2	18x3/8x3/16	Spruce	Side reinforcement
8	1*	5x5-1/4x1/16	Plywood	Camera port
9	2	5-1/4x3/8x1/4	Balsa	Camera port
10	1*	10X1/8 ID	Surgical tubing	Camera port

*Two part eights and two part tens will be needed when the aircraft is to be fitted for oblique photography.

Figure 5.6
Telemaster Modification Parts

This schedule indicates that it would take about 44 hours to construct a Butterfly aircraft. While this is not completely realistic, it is an approximation and can be a good planning guideline. The Butterfly instructions are very straightforward if they are followed step by step. The camera mount will fit better on the aircraft if you build your Butterfly as close to the kit instructions as possible. Make a few test flights before you put the camera mount on the aircraft. Chapter 6 will help you build the camera mount and put it on the Butterfly.

E. Telemaster Construction

For those building the Telemaster, twenty-four pages of detailed directions are included in the kit. Set up a building schedule that follows the instruction sequence, and follow the schedule.

To use a small SLR camera in the aircraft, the parts listed in Figure 5.6 must replace those of the original kit. There are also some new parts (7, 8, 9, &10) to add to the fuselage.

Part 7 replaces the two recommended spruce stringers on the inside of the fuselage between bulkheads 2 and 3 (see Telemaster instructions, p. 13 # 48). They are glued to the outside of the fuselage and tapered the last two inches on both ends (Figure 5.6). They go from three inches before bulkhead 2 to three inches behind bulkhead 3 on the side centerline stringers (Figure 5.7).

In the Telemaster instructions, page 10 #20, change it to read "Add the *two outer* 1/4" x 3/8" BOTTOM STRINGERS down the length of the fuselage so they butt glue to the back of the landing gear plate. *Trim both 5-1/4" x 1/4" x 3/8" cross pieces to fit against the* *back of the landing gear plate between the two BOTTOM STRINGERS. Glue one of these cross pieces against the back of the landing gear plate. Glue the camera port plywood to the bottom of the BOTTOM STRINGERS and the cross piece so both the port plywood and the cross piece are against the landing gear plate. Once the fuselage is dry, glue the other 1/4" x 3/8" cross piece on the inside of the camera port flush with the rear of the plywood part of the port. Add the center BOTTOM STRINGER so it will butt glue to the center of the back of the camera port plywood and cross piece."*

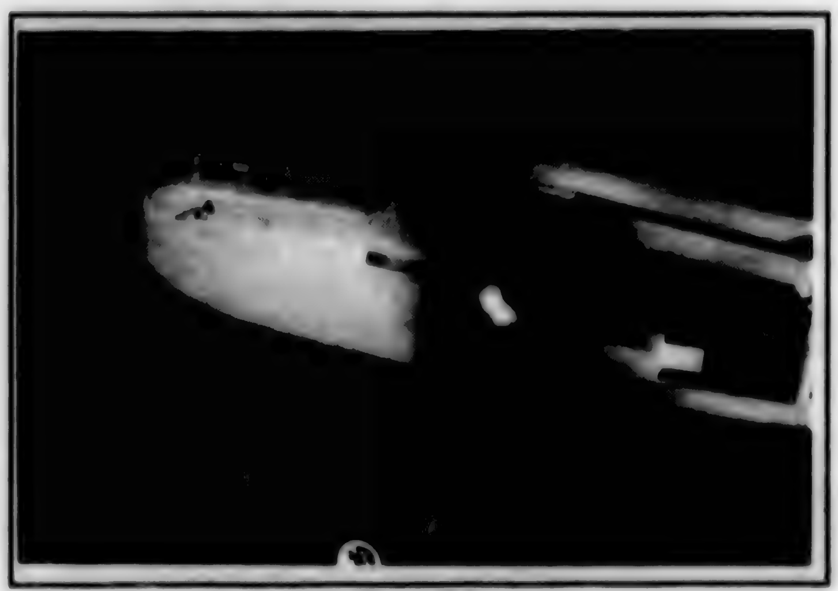

Figure 5.7
Spruce Side Stringers Modification

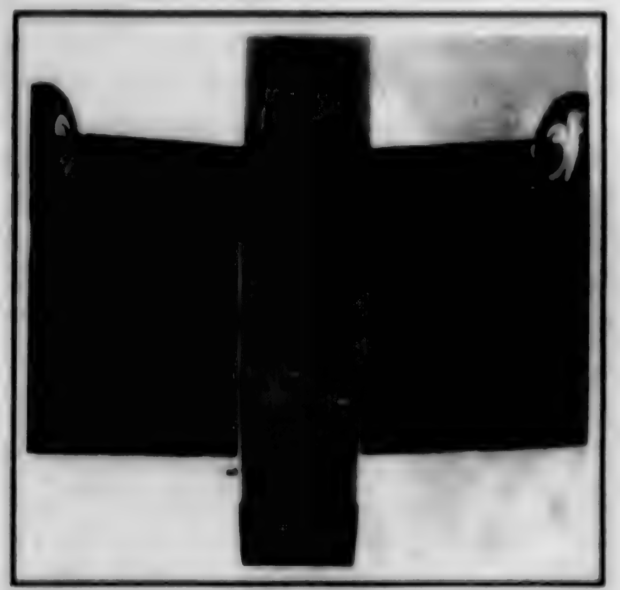

Figure 5.8
Photo of Camera Port from Outside the Fuselage

A hole must be cut in the camera port plywood for the camera lens. You may do this either before or after the camera port plywood is glued into place. It needs to be cut so that the camera will fit in the fuselage at near equal distances from either side of the fuselage and so that the center of gravity (CG) of the camera is at the center (front to rear) of the camera port plywood. *Yes, the center of the camera port plywood should be aligned with the CG of the aircraft.* The diameter of the hole should be such that the clearance between the camera lens and the hole is as close to 3/16" as possible. Once the surgical tubing has been put in place, this clearance is slightly less than 1/8". After covering the aircraft, the surgical tubing is ut in place as follows:

1. Remove covering from the hole and seal Monocote over the edge with the Monocote iron.

2. Slit the tubing lengthwise with a pair of scissors or a razor blade.

3. Start at the left rear (225° position as viewed from above) of the hole and force the tubing onto the rim of the hole (Figure 5.9).

4. After the tubing has been slid onto the rim all the way around, cut it off about 1/8" too long and force it into position.

5. *Very lightly*, put a drop of Zap glue on the joint of the tubing, and roll the fuselage around so the glue will run under the tubing all around the hole. The tubing needs to be soft (do not fill with glue or it will become hard).

Figure 5.9
Surgical Tubing in Camera Port

If you occasionally fly the Telemaster without a camera inside, it would be advisable to consider a cover for the camera port. This can be accomplished with a lens cap and masking tape, or a 1/32" plywood cover. The cover is made by concentrically gluing a 1/32" plywood disc 1/4" larger in diameter than the camera port to a disc just smaller than the port diameter. A hole is then drilled in the center of the disc and a small wood screw pushed through and screwed into another strip (1/2" wide x 1/4" longer than the cover diameter) of 1/32" plywood. The strip is slid up through the camera port, and the wood screw is then tightened to hold the cover in place (Figure 5.10).

To use the Telemaster for oblique photography, a camera port needs to be installed in the side of the fuselage opposite the exhaust side as low as possible. A camera port plywood piece is glued in place between the middle side stringer and the bottom side stringer so that the camera port is aligned with the center of gravity, as the bottom port is. Fill in the forward end between the fuselage and the port plywood with thin sheets of scrap balsa. A minor amount of trim cutting of the fuselage side may also be necessary. The sponge design for the camera mount will be discussed in Chapter 7.

Figure 5.10
Camera Port Cover

F. Weight and Balance

Nothing will fly if it is too heavy. If both aircraft are built according to the kit manufacturer's instructions, they will be within the needed weight specifications. The original LALSR Telemaster with the fuselage width change and both camera ports was only 3-1/2 ounces heavier than the manufacturer's advertised claims. The maximum weight flown in the Butterfly without a significant increase in velocity is 85 ounces; the Telemaster maximum weight is 240 ounces.

To fly, an aircraft must be balanced (this even applies to birds). Placement of servos, batteries, and the radio receiver can be used to balance of the aircraft (see *RCM Flight Training Course*, Chapter 14). Fine tuning, if needed, can be accomplished with lead weights. The weight and balance jig (Figure 5.11) is used by placing the dowels under the wing in line with the center of gravity of the aircraft. Weight is then added to the nose or tail until the aircraft is level. As you progress through the camera mounting, you will use this jig several times to ensure that the aircraft remains in balance.

With the large wingspan involved, it is necessary to balance the wings spanwise so that the aircraft does not fly in circles or with one wing low. The camera in the aircraft will not be vertical to the ground with the wing out of balance or with one tip lower than the other. Figure 5.11 shows the wing on the jig ready to be balanced. When the jig is at the center line of the wing, both wing tips should be the same distance above a level surface. Lead shot can be glued into the wing tips to bring about this balance. Once balance has been achieved, it is time to test fly the aircraft (see *RCM Flight Training Manual* and Chapter 10).

Figure 5.11
Wing on Balance Jig

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CAMERA MOUNT FOR DYNAFLITE BUTTERFLY

CHAPTER 6

The camera mount used on the Butterfly for low altitude, large-scale reconnaissance (see *Radio Control Modeler Magazine*, p 228, July 1988) can be attached to any Butterfly built according to the kit maker's (Dynaflite) instructions. In fact, I first built one to learn to fly before a camera was installed on it. This same Butterfly was then used to test three different camera mounts, and three different cameras. It has flown over 250 flights and is still in use. In a 15 mph headwind it is able to land flying backwards. Flying practice should be as slow as possible; the slower the flight, the less blur on the film. The cameras I have used thus far with the Butterfly have been the Ricoh FF series: the FF-90, the FF-90 Super, and the FF-7. To get these cameras to perform best, check the following before each flight:

1. Cover the external part of the auto focus system with black tape.
2. Make sure the auto exposure system is open so the camera can read the area in front of the camera. Remember, in this case the front of the camera looks down from the airplane.
3. In order to obtain the maximum shutter speed in most automatic cameras, the exposure value (EV) needs to be at least 16. This means using a film speed of ISO 200 on an average sunny day.

To ensure continued success, develop a checklist and follow it rigidly. It's frustrating to land after a flight and discover that the lens cover is closed or the camera control cable is not hooked up. Just about any camera of this size and type will work with the Butterfly and its mount, but the maximum weight allowable for camera, film, and batteries is 400 grams (14 ounces). It may be necessary to have a camera craftsman modify other brands of cameras for an external electrical connection; but remember, there must be no mechanical connections, because this means vibration transfer to the camera. Also remember that any rigid contact between the camera and the aircraft will transfer engine vibration from the airframe to the camera, producing a fuzzy image on the film.

There is a difference between flying the Butterfly when it is empty and when it is fully loaded. After test flying and trimming the aircraft, start adding weight at the center of gravity, and practice flying with the additional weight: Blocks of lead attached with gaffers or duct tape on the bottom of the Butterfly work nicely, and if a rough landing is involved, there is little aircraft damage. A maximum total lead weight of 18 ounces can be added. This will produce two changes in flight characteristics:

1. The elevator control reaction will seem a bit slower in terms of changing angle of attack.

2. There is a slowing reaction of rudder control at the start of a turn, and then a more rapid reaction once the turn starts. Recovery from the turn is quite rapid.

Learning to fly with these changes can be quite easy if you practice flying with increases of 6 ounces at a time until the full 18 ounces have been added.

Remember, if the weight is too far from the center of gravity, the machine will crash, because nothing that is unbalanced will fly. Once flight proficiency at full weight has been achieved, add the empty camera mount on over the weights and fly it again. Notice that the mount causes no additional change in performance. Now replace the lead weight with the loaded camera and fly your first photo flight.

The Butterfly with a .15 engine has been flown at a gross weight of 85 ounces. This weight has been hand launched at field altitudes varying from 150 feet and 9,200 feet above sea level. Flying at higher altitudes requires more patience and a change in engine needle valve setting.

A word of caution about flying the Butterfly with larger engines: with a larger engine the Butterfly flies fast and is very maneuverable, but it has too many vibration problems and too much velocity for reconnaissance. With larger engines, the RPM must be low to achieve slow flight. A slow-turning prop introduces problems with airflow around the camera mount, and this causes the mount to vibrate. A .15 to .20 engine gives plenty of power for this aircraft in the slow speed range and provides for optimum imagery.

A. Building the Mount

The camera mount plans are at the end of this chapter, along with the list of materials. Best results are achieved with the recommended material. The points at the front and rear on the side of the mount are critical for vibration dampening. Do not alter the 12-inch distance between them more than 1/4". Keep the rear point as pointed as possible without it becoming a safety hazard.

Cut the mount with a sheetrock knife and metal ruler (Figure 6.1). Glue the entire mount together with cyanacroiate glue (filled type) except the rear cross-brace. Glue it with Titebond. Fit and clamp closely so that the glue will work properly. Coat the mount with three coats of polyurethane varnish inside and out to finish it. Use a piece of Monocote to cover the space between the mount bottom and rear cross-brace (Figure 6.2). Install the four grommets and glue the bottom sponge (spider foam) in place with foam glue. Place all other pieces of sponge around the camera each time it is installed in the mount (Figure 6.3).

Sponges were cut out with a GE electric slicer for the original mount. A few notches had to be cut into the bottom sponge when the Ricoh FF-90 Super was used--just enough to ensure that the hand grip and left side front rib float free of any contact.

At this point glue the bottom sponge onto the spider foam which has already been glued to the bottom of the wood part of the mount. Gray spider foam is the 1/4" light-density foam that is used for packing projection light bulbs and computer parts. Load the camera with film and place it on top of the sponge. Using a pencil, screwdriver, or skewer stick, push the side sponges in place, then the front and rear sponges (rear last). Now place the top sponge on the camera so it will fit between the camera back and fuselage bottom.

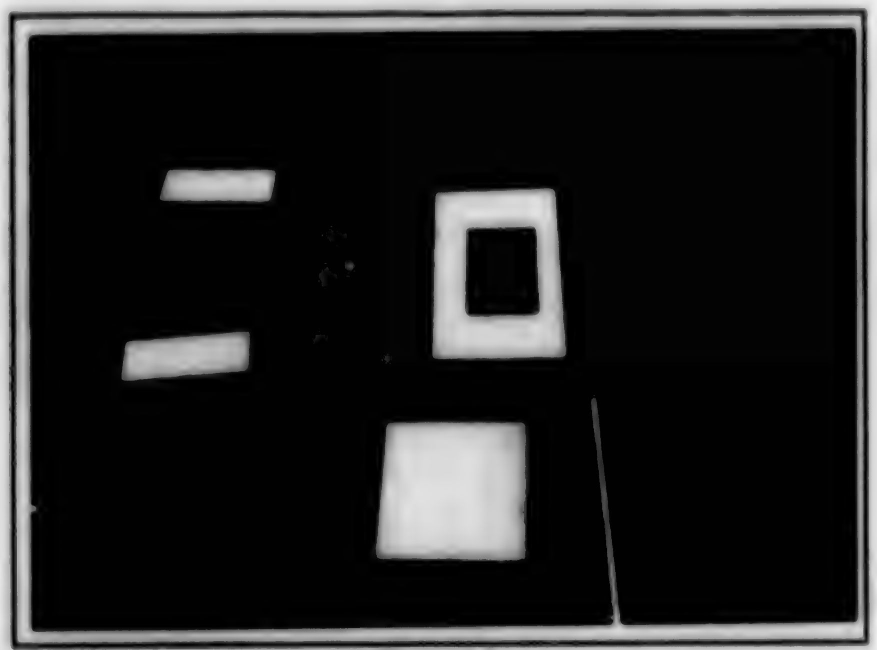

Figure 6.1
Cutting Out Camera Mount

Figure 6.2
Mount Showing Rear Brace Covered

Figure 6.3
Camera in Mount with Sponge

With camera and sponge in place, determine the center of gravity of the camera mount. This can be done by using a 6" long 3/4" diameter dowel sanded flat on one side. Place the dowel flat side down on a table and move the camera mount across the dowel until the mount balances. Mark the point at which the mount and the dowel are in contact with each other (CG) on both sides of the mount (Figure 6.4). Place the mount on a flat table and mark a vertical line with a triangle along each side of the mount (Figure 6.5).

B. Center of Gravity Alignment

Mark the Center of Gravity of the Butterfly on each side of the aircraft. Draw a line at right angles to the wing saddle down each side of the fuselage. Tape the camera mount on the bottom of the fuselage. The lines on the side of both the mount and aircraft should meet at the bottom of the fuselage, at an angle of 6° to 7° (Figure 6.6). This levels the camera during flight. The fit between mount and fuselage should be firm but not too tight. Use a 1/8" drill to mark through the grommet onto the side of the fuselage. Remove the camera mount and make sure there is room all around the drill mark for the hole for the well nut. Drill the holes to fit the well nuts snugly. The forward well nut holes should be in the fuel tank compartment. Cut out wood washers to fit on the well nuts on the inside of the Butterfly fuselage (Figure 6.7). Bevel the washers on the bottom half so they will fit inside properly. Glue these washers in place (Figure 6.8) and fit the well nuts into the fuselage (Figure 6.9). They will protrude approximately 3/32" outside the fuselage and just barely touch the camera mount. The opening for the camera operating plug in the fuselage can be drilled in the bottom or left side near the rear of the mount away from the exhaust side of the aircraft. It should be just large enough for the plug to be forced through. Hold the rear sponge down and plug the trigger (see Chapter 8) into the camera. When you release the sponge, it will insulate the plug from the mount. Next place the top sponge over the camera and squeeze the camera

Figure 6.4
Marking Center of Gravity (CG) on the Side of the Camera Mount

and mount up onto the bottom of the fuselage. Secure the mount to the airplane with a #6-32 screw through each grommet (4) into a well nut, and soft-touch tighten them (Figure 6.10). The aircraft is now ready to fly with the camera on board.

C. Tuning

Remember, the last thing to do before launching the aircraft is to open the camera lens. Make several passes at elevations between 200 and 600 feet. After the flight, process the film and examine the results. If there is directional blur on the film, the aircraft is moving too fast; if it is circular, then it is probably caused by powerplant vibration. The source of the vibration can be found and reduced in the following way. Put the camera back into the mount and on the aircraft. Start up the engine and run it at cruising rpm. Put the probe of a mechanic's stethoscope on the camera (Figure 6.11), and listen while pressing a soft eraser in the nibble zone of the camera mount. The point of eraser contact that reduces the sound in the stethoscope is the area where wood should be removed. On the original aircraft, this wood was removed with a 1/4-inch hand paper punch, then smoothed with sandpaper. The noise will not be totally eliminated because of the air acoustics around the stethoscope, but it can be reduced. After a few trimmings and flights, photos should be sharp and clear, capable of producing twenty-diameter enlargements.

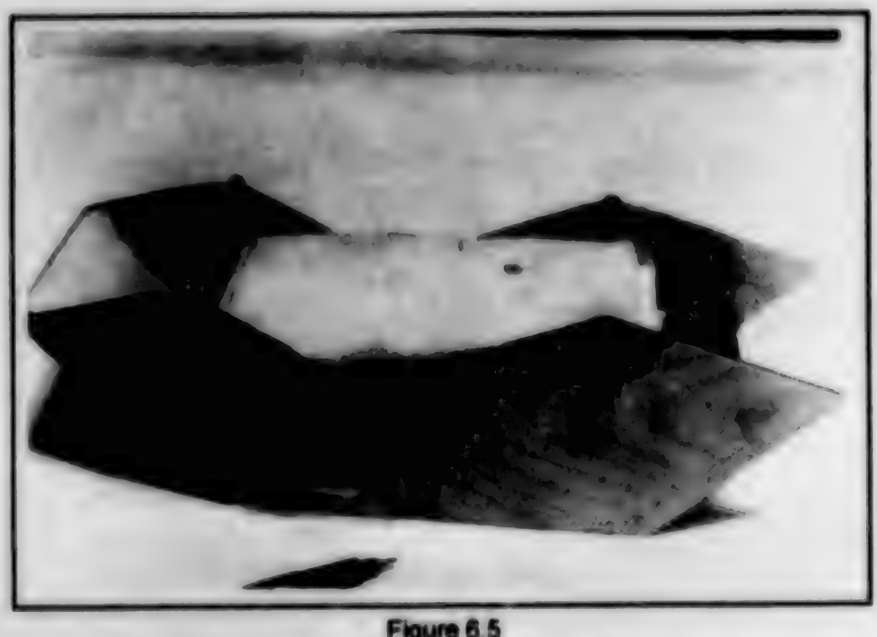

Figure 6.5
Vertical Line at the CG on the Side of the Camera Mount

Figure 6.6
CG Lines Meeting on the Side of the Camera Mount and the Side of the Fuselage at 6"

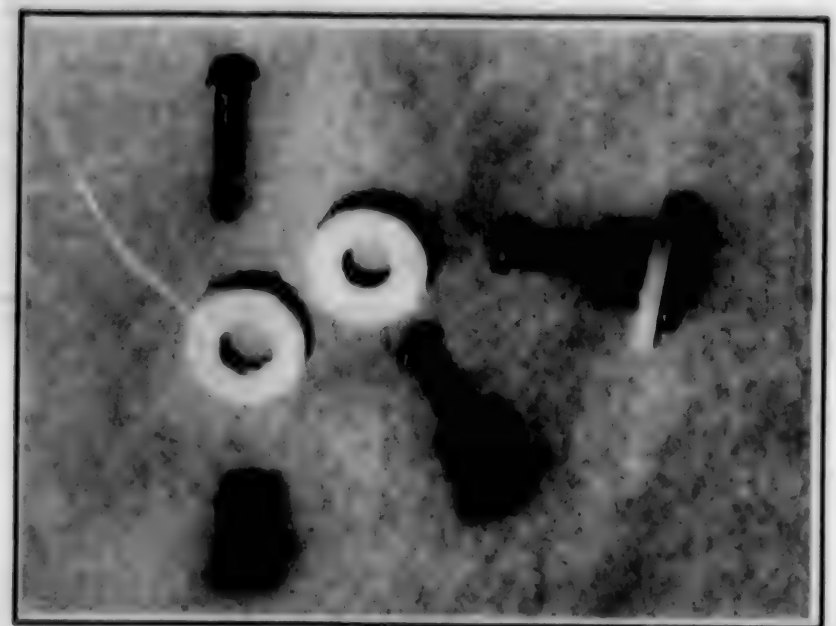

Figure 6.7
Wood Washers and Well Nuts

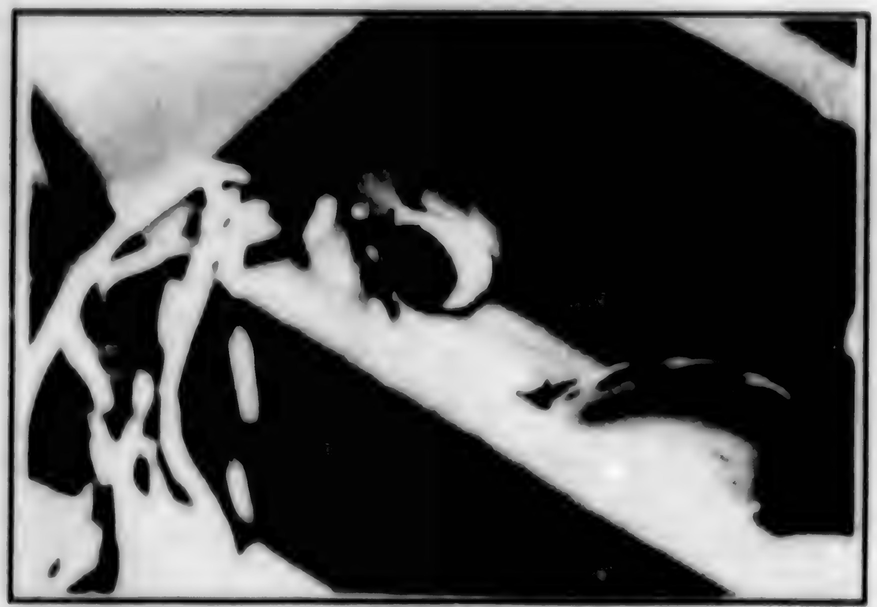

Figure 6.8
Wood Washers Glued in Plac

Figure 6.9
Pulling Well Nuts Through Fuselage

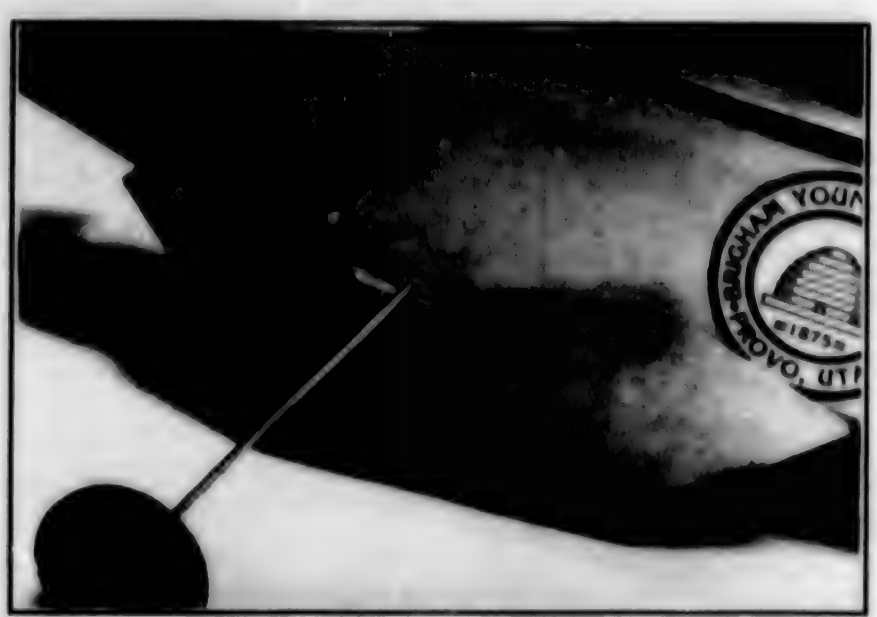

Figure 6.10
Mounting Screw Through Grommet and Camera Mount into
the Well Nut with the Mount in Place

Figure 6.11
Using a Mechanics Stethoscope and an Eraser

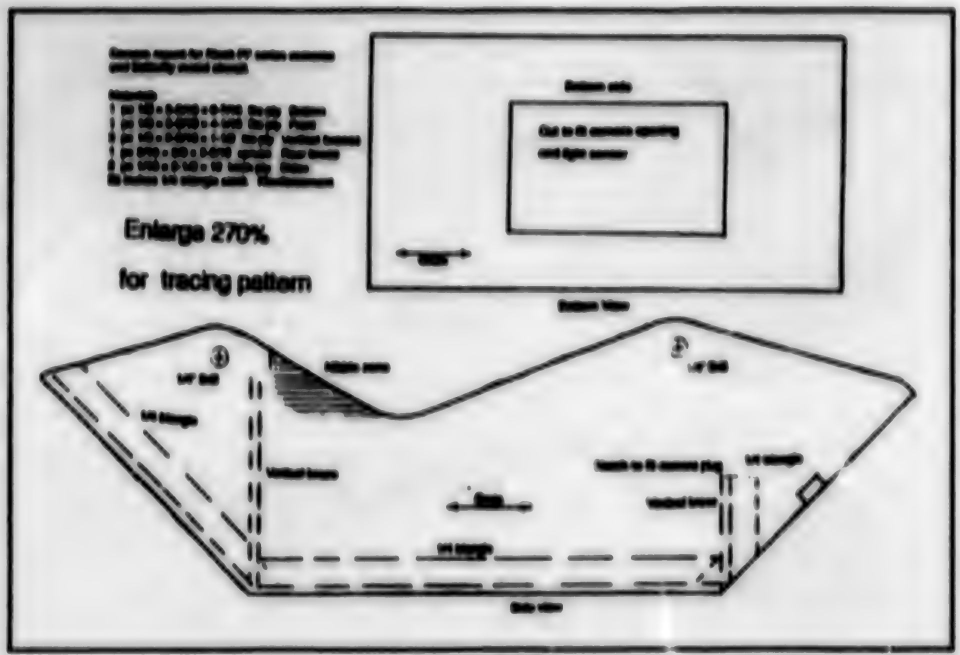

Figure 6.12
Drawing of the Camera Mount and its Parts

D. Materials Needed

1 Piece 1/8" x 3-5/16" x 6-7/16" lite plywood
1 Piece 1/8" x 3-5/16" x 4-1/16" lite plywood
2 Pieces 1/8" x 3-5/l6" x 1-1/2" lite plywood
1 Piece 3/16" x 3/8" x 3-5/16" spruce
2 Pieces 1/16" x 3-1/2" x 12" birch plywood
1 Piece 26" x 3/8" balsa triangle stock
4 Pieces 1/8" Lite plywood 1/2" square (well nut washers)
4 Rubber grommets to fit in 1/4" holes
4 #6 rubber well nuts
4 #6-32 screws, one inch long
1 Piece Goldberg latex sponge 1/2" x 3-1/4" x 6-1/4" (cut out for camera lens to match plywood)
1 Piece Gray spider foam 1/4" x 3-1/4" x 6-1/4" (cut out for camera lens to match plywood)
1 Piece Goldberg latex sponge 1/4" x 3-1/4" x 6-1/4" (top sponge)
2 Pieces Goldberg latex sponge 1/4" x 1 1/4" x 5-1/2" (side sponges)
1 Piece Goldberg latex sponge 1/2" x 1" x 3" (rear sponge)
1 Piece Goldberg latex sponge 1/4" x 1-1/2" x 3 (front sponge)
1 Piece Sponge weatherstrip 1/4" x 1/8" x 3-3/8"
1 Piece Monocote 3" x 4"
Titebond glue
Polyurethane varnish
Masking tape.

All Goldberg foam pieces can be cut from one sheet of 1/2" and one sheet of 1/4" foam of the size sold in hobby stores.

E. Tools Needed

1 Screwdriver (to attach camera mount)
1 Applicator for varnish
1 Flat-bottomed 3/4" dowel
1 Plastic triangle
1 Fine felt-tipped marker
1 1/8" drill
1 1/4" drill
1 1/4" hand paper punch, or aluminum nibbler for nibbling camera mount
1 Long, thin screwdriver or mechanic's stethoscope
1 Electric slicer
1 12" ruler (metal)
1 Sheetrock knife
1 2" long 1/4" soft pencil eraser.

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TELEMASTER CAMERA MOUNT

CHAPTER 7

The camera and its mount are totally enclosed in the Telemaster aircraft fuselage. Only the front of the camera lens protrudes from the bottom of the fuselage about 1/8" (if a haze filter is used). This applies to any camera used in the Telemaster. Design calculations were made for using polyurethane foam with this mount. The all-balsa and near total lack of lite-ply plywood used in the aircraft's construction introduces some vibration problems that are cured by placing a piece of 1/2 pound per cubic foot foam (2" x 2" x 4-1/4") in the back part of the camera and servo compartment. This piece of foam should be able to float free and is held in place by gravity. Remember that foam surrounds the camera and insulates it from contact with any other part of the aircraft. The only thing touching the camera aside from the foam is the trigger coax. Most of this mount construction is "fit on assembly."

A. Construction

Most foam is available in densities measured in pounds per cubic foot. Upholstery shops and hardware stores have polyurethane foam stocked by density. The original mount was cut from the end of two densities of foam mats and some other scraps from an upholstery shop.

Cut out the pieces of foam according to the "Materials" list with an electric slicer or a pair of long scissors. The cutting does not have to be too smooth; in fact, if it is, your mount may require more tuning than most other mounts. Round all corners--square corners have a tendency to build up vibration concentrations. Mark each piece with a marker that does not dissolve the foam. Glue the three pieces of 4" x 6" foam together with the highest density on one side, the least dense on the other, and with the medium density in the middle (Figure 7.1). Use the adhesive sparingly and allow it to nearly dry before sticking the pieces together. Also be sure the adhesive you use dries flexible and not rigid.

When dry, cut a hole through the three pieces of sponge about the diameter of the lens in such a way that the camera fits behind the rest of the sponge (Figure 7.2) and the lens protrudes into the foam. This positioning will vary according to the brand and model of camera, as will the following two cuts.

Next, cut a space from the less dense foam (1/2") to allow the penta-prism of the camera to float free of the foam (Figure 7.3). The final cut will allow the motor drive room to fit without compressing the foam. It is cut from the same side of the foam as the penta-prism cut (Figure 7.4). Now give all the foam a four-hour sun bake; that is, place each of the camera mount pieces of foam in bright sunlight for four hours. This seems to soften the foam a bit and help attenuate vibration. Then you are ready to place the foam and camera into the aircraft and test your mounting.

Figure 7.1
Gluing of the Three 4" x 6" Pieces of Foam

Figure 7.2
Center-cut Hole in the Three-piece Foam

Figure 7.3
Clearance Cut for the Penta-Prism

Figure 7.4
Final Cut on 4" x 6" Foam

B. Loading, Fitting and Flying

It is assumed that the Telemaster has been flown before the camera is tested in flight. If not, fly the aircraft to trim it and to understand its flight characteristics as described for the Butterfly.

Place the damper sponge (2" x 2" x 4-1/4") under the servos and behind where the camera is going to be mounted. Load the camera with film, set the exposure, and focus the lens at infinity. Tape the lens so that neither the focus nor the exposure will change during flight (Figure 7.5). Most lens-focusing mechanisms on 35mm cameras unwind in an aircraft during flight and thus change the focus, so *tape the lens well.* Place the camera in the cut foam piece (Figure 7.4), and then place it in the fuselage so that the haze filter part of the lens protrudes very slightly through the fuselage. The haze filter is used as a protective in-flight lens cover. It does not touch the surgical tubing of the lens opening. Hook up the trigger (Chapter 9) and turn on the camera motor drive. You may also want to test the trigger circuit before going further. Push into place the two pieces of foam which were cut to fit between the sides of the fuselage and the camera top and bottom. Place the 1" x 4-1/2" x 5" piece of foam between the servos and the camera. Place the 1" x 4" x 6" piece of foam on the side of the camera that is toward the nose of the aircraft. Use a couple of pieces of 0.7-lb foam to fill in the space between the front of the camera foam and bulkhead 2. This must be trimmed and fit on assembly. It should be fit to stop camera movement, but it should not be too firm. Place the 1" x 3-1/2" x 5" piece of foam on the camera back and tuck it to fit where necessary. Then lay the trigger circuit on top of the foam (Figure 7.6), and place the 3/4" x 4-1/4" x 6-1/4" piece of foam on top of the trigger and above the 1" x 3-1/2" x 5" foam (Figure 7.7).

Figure 7.5
Taped Lens

Figure 7.6
Camera Mounted in Sponge with Trigger Circuit in Place

Figure 7.7
Full Camera and Mount

Now plug in the aileron servo, put on the wings with rubber bands, and align the wings. Check the center of gravity to make sure it is still where it should be. If it is not in the proper place, then balance the aircraft before you fly it (Figure 7.9). Follow your checklist (see Figure 10.9) to get the aircraft into the air. Do not forget to remove the lens cap before takeoff. Make a few higher altitude passes (600 feet) while trimming for the slowest flight speed. Then make a couple of passes over a fairly high-contrast measurable target and expose the roll of film. After landing, get the film processed and printed. Check the imagery for sharpness with a magnifier. If you have a measuring magnifier, measure the target length and width on the film (Chapters 11 and 13). If the length-to-width ratio has not changed, then any blur you may have is due to vibration, not motion. If the camera did not touch the fuselage of the aircraft, and there is still vibration, then it could be due to smooth spots along the narrow dimension of the "front of the camera" sponge, close to one of its corners. Picking off a corner of the sponge that is closest to the smooth side will usually cure this problem (Figure 7.8).

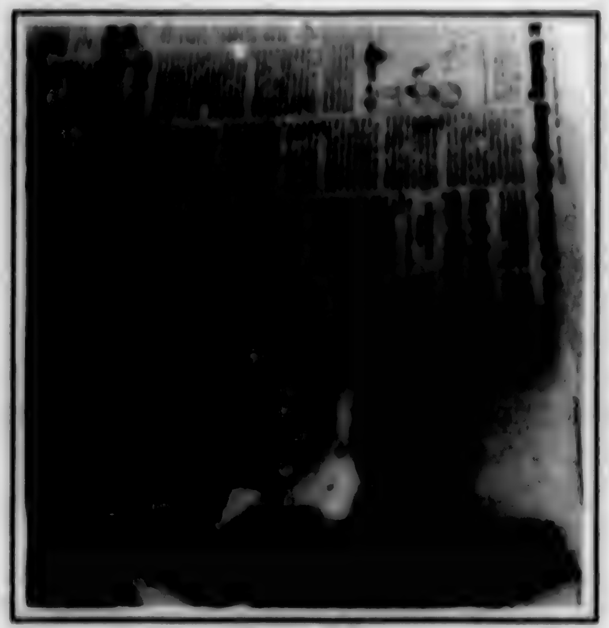

Figure 7.8
Picking Off a Foam Corner

Nothing has been said about the vertical placement of the camera with respect to the ground for the Telemaster, as it was with the Butterfly. This is because the angle of attack of the wing and the slope of the floor board (camera port) leave the camera level in flight if the sixteen-ounce tank recommended for the aircraft is at least half full. This allows twenty-five minutes to complete a photographic mission with the original Telemaster that was built for LALSR work.

C. Oblique Mount

Only one additional piece of foam is needed for the oblique mount on the Telemaster. It is a 2" x 4-1/2" x 8-1/4" 0.5 pounds per cubic foot piece of gray foam for cutting an interface angle to depress the lens so it does not photograph the wing tip of the aircraft. This depression angle is just under fifteen degrees; however, it can be increased by cutting a larger angle in the gray foam. Two different angle sponges have been cut for use with the original LALSR Telemaster. These are fifteen-degrees and twenty-five degrees. Therefore, whatever angle you need within the limits of the aircraft is measured along both the 4-1/2" sides of the foam (Figure 7.10). Cut the piece of foam in two and glue it in the shape shown in Figure 7.11. When the glue is dry, place the foam in position in the fuselage and mark the lens opening on the foam through the oblique camera port (Figure 7.12). Remove and cut out the lens opening. Now cut out space for the camera penta-prism and motor drive (the same as for the vertical mount sponge). Then cut off the excess sponge from the forward end of the vertical part of the sponge mount (that which does not have a camera next to it). The end product should look like Figure 7.13.

The load on the oblique-positioned camera is not the same as in the vertical position; that is why the gray foam is used. To use the camera in the aircraft for oblique photography, go through essentially the same routine to load, set the exposure, tape the lens, and hook up the trigger. Place the oblique lens foam on the front of the camera and set it in place in the aircraft (Figure 7.14). Position the camera so the lens does not touch the surgical tubing. Place the two pieces of 1" x 3-1/2" x 6" foam together and between the opposite fuselage side and the camera back. Place the 1" x 4-1/2" x 5" piece of foam between the servos and the camera. Place the 1" x 4" x 6" piece of foam on the side of camera toward the nose of the aircraft. Use a couple of pieces of 0.7 pound foam to fill in the space between the front of the camera foam and bulkhead 2. This must be trimmed and fit on assembly. It should be fit to stop camera movement, but it should not be too firm. Place the 1" x 3-1/2" x 5" piece of foam on top of the camera and tuck it to fit where necessary. Then lay the trigger circuit on top of the foam (Figure 7.6) and place the 3/4" x 4-1/4" x 6-1/4" piece of foam on top of the trigger and the top of the 1" x 3-1/2" x 5" foam (Figure 7.7). At this point, the aircraft is ready for testing. Good luck! The results should be surprising and exciting.

Figure 7.9
Center of Gravity Check

Figure 7.10
Angle Mark for the Oblique Camera Mount Foam

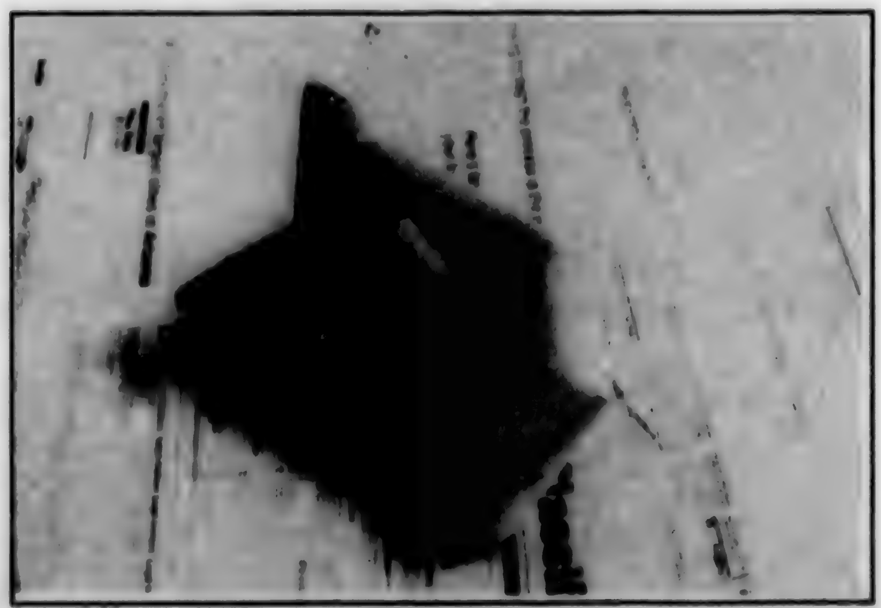

Figure 7.11
Glued Oblique Camera Sponge

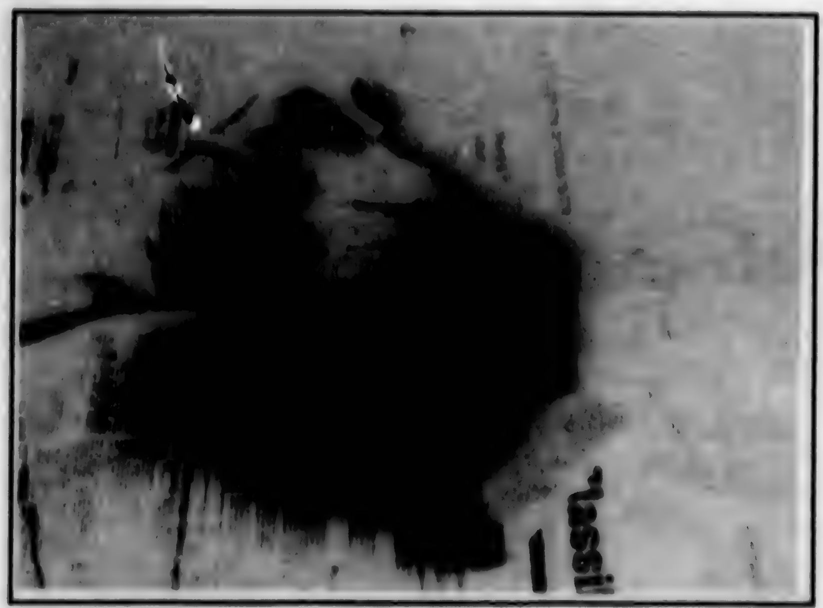

Figure 7.12
Marking Lens Opening on the Camera Mount

Figure 7.13
Oblique Foam with Camera

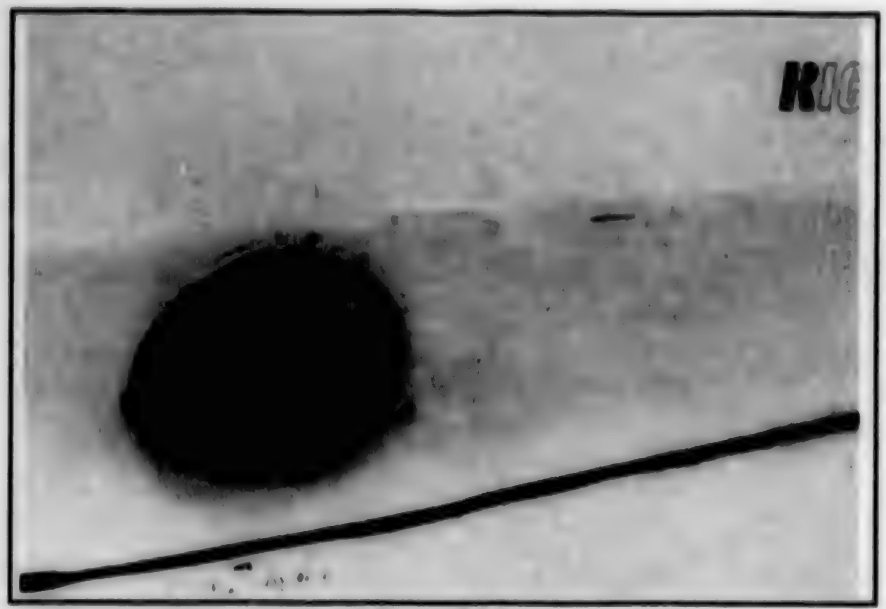

Figure 7.14
Oblique Mount and Camera in Position

D. Materials Needed

1. Vertical Mount

   1 Can sponge spray adhesive (very little is needed)
   1 Piece 1" x 4" x 6" 0.9 lb foam (front of camera)
   1 Piece 1" x 4" x 6" 0.7 lb foam (front of camera)
   1 Piece 1/2" x 4" x 6" 0.5 lb foam (front of camera)
   2 Piece 1" x 3-1/2" x 6" 0.7 lb foam (top and bottom of camera, fuselage sides)
   1 Piece 1" x 4-1/2" x 5" 0.5 lb foam (rear of camera mount, towards tail)
   1 Piece 1" x 4" x 6" 0.7 lb foam (front of camera, towards nose)
   1 Piece 1" x 3-1/2" x 5" 0.5 lb foam (top, covers camera back)
   1 Piece 3/4" x 4-1/4" x 6-1/4" 0.7 lb foam (covers top sponge)
   1 Piece 2" x 2" x 4-1/4" 1.2 lb foam (floating behind camera and under servos).

2. Oblique Mount

   1 Piece 2" x 4-1/2" x 8-1/4" 0.5 lb gray foam (for cutting interface angle).

E. Tools Needed

1 Electric slicer or long pair of scissors
1 Mechanic's stethoscope.

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UU & UU-2 AIRCRAFT

CHAPTER 8

Two new aircraft have come into existence through the LALSR program: the UU and the UU-2. They evolved as a result of continued usage of the Butterfly and the Telemaster, and student questions concerning the basic design of camera mounts. A new set of calculations resulted in another method of mounting cameras. This new method of mounting will allow the continued use of some of the parts of the Butterfly aircraft. Most of the modification is fuselage shape, with the addition of graphite stiffening. Performance exceeds the previous configuration in terms of vibration reduction, rate of climb, and control response. Use of a 4-cycle power plant in these two aircraft also improved the vibration and rate of climb.

During winter semester of 1991, the second class in low altitude large-scale reconnaissance was taught at Brigham Young University. Two of the students, mechanical engineering majors, asked why the camera was carried external to the fuselage on the Butterfly aircraft (The Butterfly aircraft has been the primary machine used with the LALSR classes.). An explanation of the vibrations within the fuselage and the use of the well nuts to eliminate these vibrations in the camera mount seemed satisfactory until the critical length of the camera mount was emphasized. Then these two inquiring students asked if this critical length could be used within the fuselage to create either a soft or a rigid vibration control area. This question sent one of the instructors of this team-taught class back to the drawing board.

A. 11.9 Inches

Five years ago, it was determined that the critical dampening length in wood from an internal combustion engine operating at 5,000 to 7,000 revolutions per minute is 11.9 ± 0.3 inches. This is not the critical wavelength of that frequency range, but the length of a wooden object which best tends to dampen vibrations in the 5,000 to 7,000 cycle range. To dampen vibration in the structure around the camera, there needs to be some place where the vibration can either be carried away in the form of stress or passed along through structure. Inasmuch as the fuselage is considerably longer than 11.9 inches, the original camera mounting on a Butterfly was external and in a mount that was slightly under 12 inches (11.9) long. All performance with this mount has been excellent, but the idea of internally mounting the camera was desirable for both safety and camera protection. Several crude tests were made with pieces of wood with graphite, boron and fiberglass strips epoxied to them. These pieces were placed in contact with a 6,000 cycle vibration source, and dampening checked with a mechanics stethoscope. From a sound standpoint, it was determined that an 11.9 inch length of 1/8-inch-wide graphite epoxied on wood worked better than the other materials we tested to dampen this particular type and frequency of vibration. It was further discovered that running two of these strips parallel to each other induced a secondary vibration that was as bad in magnitude as the 6,000 cycle vibration. Inasmuch as a reinforcement is needed on both sides of the camera mounting area, further tests revealed that placing these two strips at an angle of more than 10° eliminated this secondary vibration. This creates a semirigid fuselage compartment around the camera.

Therefore the following instructions were given to students who wanted to try mount their cameras inside the Butterfly fuselages: "Before gluing your fuselage sides together, epoxy a 12-inch long strip of 1/8-inch wide carbon fiber along the inside of each side of the fuselage in the compartment area. Make sure each strip is not parallel to the strip on the opposite fuselage side. Cut your bulkheads to be at least 3/8-inch wider than the width of the camera you are using. Sand a small groove on each edge of the bulkhead with an emery board so the carbon fiber will fit through it and the bulkhead will fit tight to the fuselage side." See Figures 8.1 and 8.2.

Two new fuselages appeared, neither looking like the fuselage which was originally pre-visualized (Figure 8.3). Both fuselages performed well--all expected parameters were met or exceeded; however, since they were different looking than the fuselage previsualized, a third fuselage had to be built. In addition to the previsualized shape, the new fuselage absorbed some of the attributes of the two student fuselages, including a fiberglass landing gear. This landing gear is stronger, more flexible, and lighter in weight than the standard Butterfly landing gear.

Figure 8.1
Fusealage Insides Prior to Assembly, Showing Carbon Fiber Strips

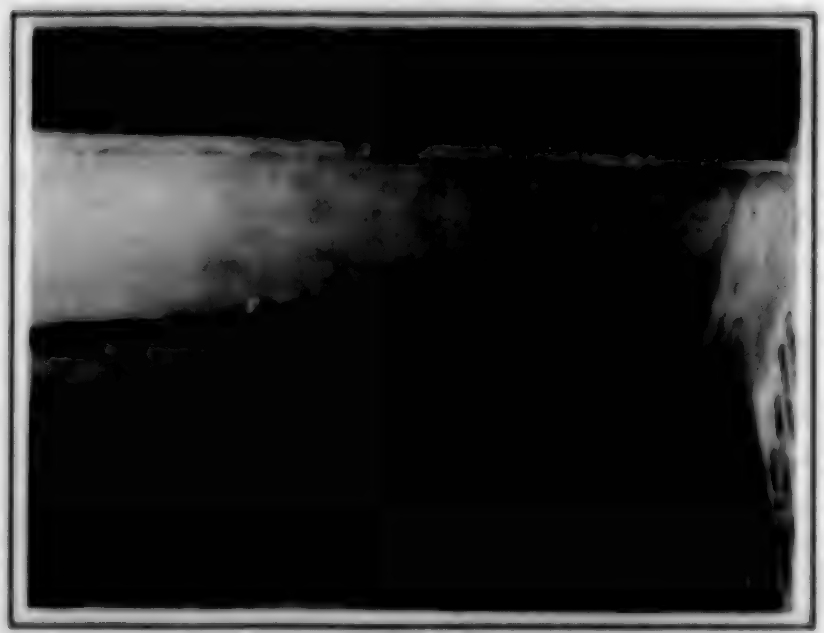

Figure 8.2
Fuselage After Assembly, Showing Carbon Fiber Strip Running Under the Bulkhead

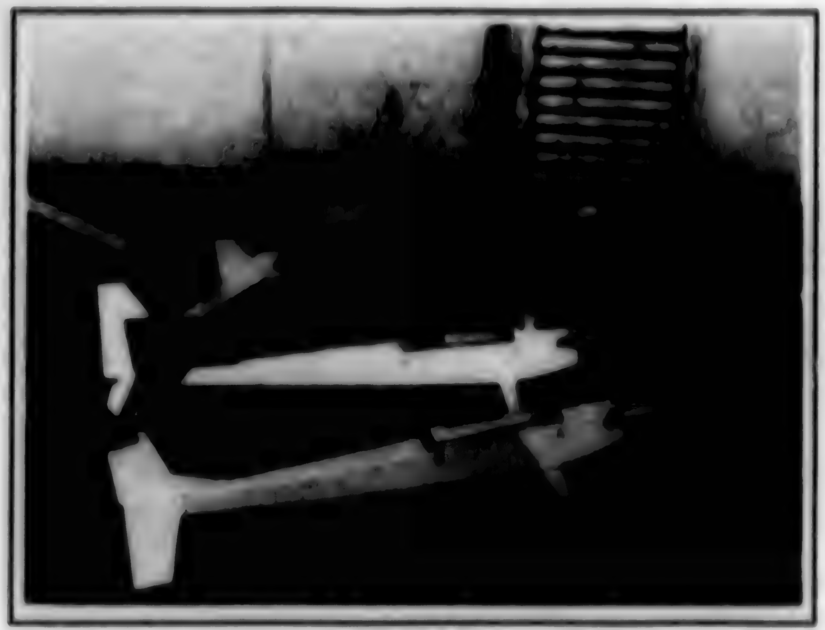

Figure 8.3
Four Different Fuselages Built from the Same Set of Calculations

B. Performance

"Phenomenal" was the word used to describe the performance of the first flight of the new fuselage with the standard Butterfly wing. The aircraft took off from a soft sandy beach and climbed to just over 600 feet in under 50 seconds. It has a sink rate that makes landings very long and slow. Because of the slow sink rate when empty, this fuselage has not flown without a camera or other ballast since the first flight. It was nicknamed the UU, because of its unusual performance. It has flown with up to 25 ounces of ballast with little or no effect on its performance. Its forward velocity is about the same as or slightly slower than the standard Butterfly. This machine has now been used very successfully to fly several reconnaissance flights. It is fast replacing the standard Butterfly and is now itself being replaced by a newer and slightly larger version of itself called the UU-2. The development of this newer aircraft was spurred by student comments and suggestions about the performance of the UU. The UU-2 has the same power as the UU, a longer wing span (105 square inches more wing area), and a wider fuselage to hold a camera with a 1/2000 of a second shutter speed. The performance of this machine is slightly better for LALSR than the UU. The biggest advantage to the UU-2 is the fast camera shutter speed, which delivers a 0.21-inch image motion (IMP) capability during exposure.

C. Resultant Design Changes

1. Fuselage Changes

The fuselage width of the UU is 9/16 of an inch wider than the standard Butterfly to accommodate internally the Ricoh FF series cameras being used with the Butterflies. The fuselage height is increased 1-7/8 inches to allow the camera to fit at a lower level in the compartment than the servos. A camera viewing hole is cut in the bottom of the compartment the same dimensions as in the old Butterfly camera mount. The same sponge mounting material is used as was in the old mount (Figure 8.4).

The fuselage width of the UU-2 is 1-1/4-inches wider than the standard Butterfly to accommodate the new camera with the higher shutter speed. The fuselage height is increased by 3-3/8 inches to allow a Ricoh KR-10m camera to fit, and the fuselage length was increased 10%. A round hole is cut in the bottom of the compartment to allow this new camera to see vertically. A new camera sponge mount had to be designed to accommodate the new camera (Figure 8.5). The height of this larger fuselage is such that some special but simple clamping is needed for gluing during its construction. This clamping is to achieve good bonding and contact up the full height of the forward bulkhead.

The previously mentioned graphite epoxy strips and reinforcement for the new landing gear are also fuselage modifications. The new landing gear are actually more simple to install than is the standard Butterfly gear.

2. Tail Feathers

The tails of the two new machines are essentially the same as the original Butterfly, although the rudder area of the UU-2 is increased by 4.5 square inches.

3. Wings

The UU wings are a set of standard Butterfly wings, built as per kit instructions. The slow speed performance of the UU is a bit phenomenal. It really needs ballast to help it land properly and to prevent thermaling during regular flight activities. The UU-2 wing span is 10 inches longer than standard Butterfly wing (Figure 8.3). It uses either a standard Butterfly airfoil or a Gottengen 489 airfoil. The UU-2 aircraft will also fly with a standard Butterfly wing.

4. Camera Changes

Although the UU works well with the Ricoh FF series cameras, minimum image motion (IMP) is 0.528 inches because of its 1/400 second shutter speed. Use of a camera with near 1/2000 second shutter speed will reduce the IMP to 0.21 inches. The reason for the development of the UU-2 was to be able to fly a camera with 1/2000 of a second shutter speed in an aircraft as portable, as easy to fly, and as stable as the Butterfly. Ricoh was contacted and again willingly furnished one of its KR-10m cameras for the test. At the time (winter and spring 1991), this was the lightest weight and smallest camera on the market with 1/2000 second shutter speed, auto-wind and an electronic cable release. Fully loaded with batteries and film it weighs 24.5 ounces. The UU-2, loaded with camera and full fuel, weighs 102 ounces; the UU and the Butterfly weigh 84 ounces.

5. Radio Changes

During the past five years there have been problems with deterioration of the black plastic on the transmitter cases of the radios used with LALSR. Most of this deterioration is due to solar ultra-violet radiation, and with the increase in the amount of this black plastic in most of these radios, there was a need to find an all metal transmitter case; therefore, a radio was purchased from Ace R/C in Higginsville, Missouri. Ace R/C manufactures an all metal transmitter case that should handle the environment better than plastic. This radio unit has performed very well so far, and takes the rough treatment involved with LALSR. During the spring at a field workshop at the Pinion Canyon Maneuver Site, a discussion was held about the console on the transmitter and how it could be better designed for LALSR. As a result Ace R/C was contacted, and with its help a new console was designed that seems to work better, especially with camera triggering (Figure 8.6). To date both the UU and UU-2 have flown only with Ace radios.

6. Power Plant Changes

During the time that the development of the new aircraft was taking place, testing of four-cycle power plants was also being accomplished for other reasons. The vibration frequencies of both two and four-cycle power plants are about the same at the cruising velocity of the UU and UU-2. The amplitude of this vibration is smaller with the four-cycle power plant, and this lower amplitude makes sponge design much easier in terms of thickness and compression. The power plant tested and later used on all flights of both the UU and UU-2 thus far has been an OS-26 four-cycle model engine. The results are obvious in the imagery.

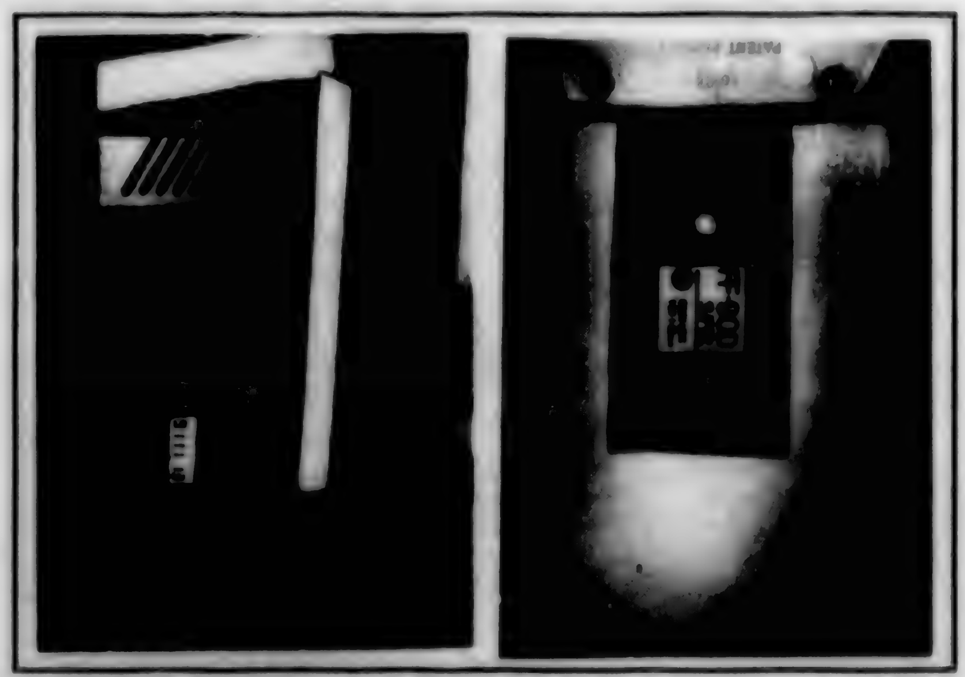

Figure 8.4
Top and Under Views of the Ricoh FF-90 Mounted in a UU Fuselage

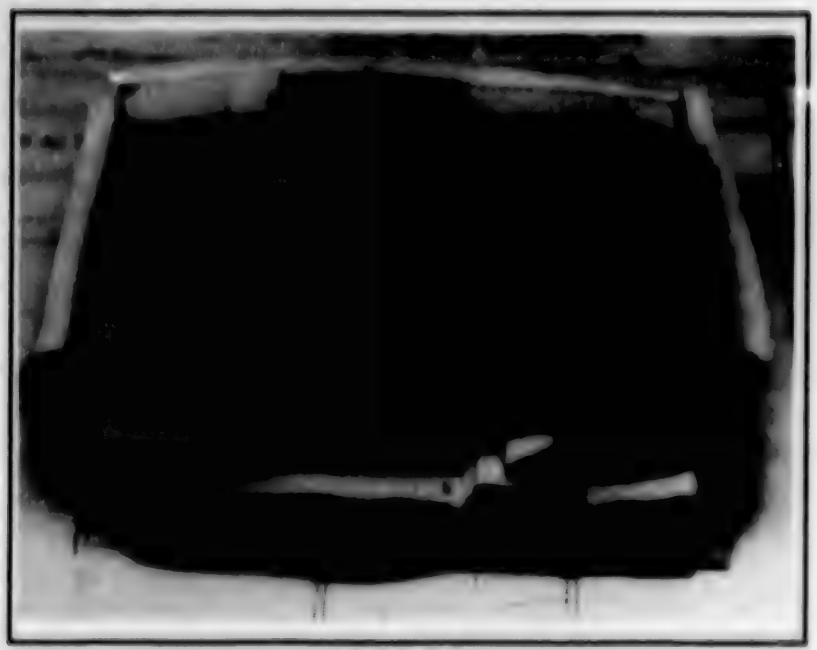

Figure 8.5
Ricoh KR-10m in its Sponge Mount

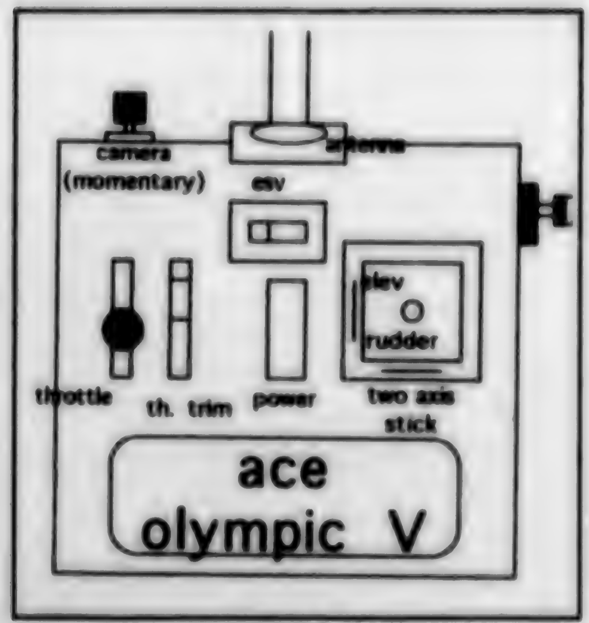

Figure 8.6
New Ace Transmitter Console for LALSR

D. Result of UU and UU-2 Flights

The first flight of a UU-2 with a camera on board and the long wing was on August 19, 1991. The following are excerpts from the flight log: "The UU-2 was flown with a KR-10m camera, and the long wing. The results were quite surprising. Flight characteristics were not as difficult as expected, and rate of climb was better than anticipated. The imagery was phenomenal, to say the least. Cracks from a dry lake bed were very visible, along with gold lettering on a green folder through a glass window (Fuji Neg. Film, ISO 100) in an automobile" (Figure 8.7). On September 16, 1991, a lava dike in the Staircase region at Capitol Reef National Park was photographed with amazing results, and "the total effect will require comparison with USDA imagery." The imagery comparison can be seen in Figures 8.8 and 8.9.

These two aircraft have good stable flying characteristics. They can be easily hand launched when needed and are as portable as the Butterfly aircraft has been. Plans for the two aircraft and a thirty-page set of building instructions are available.

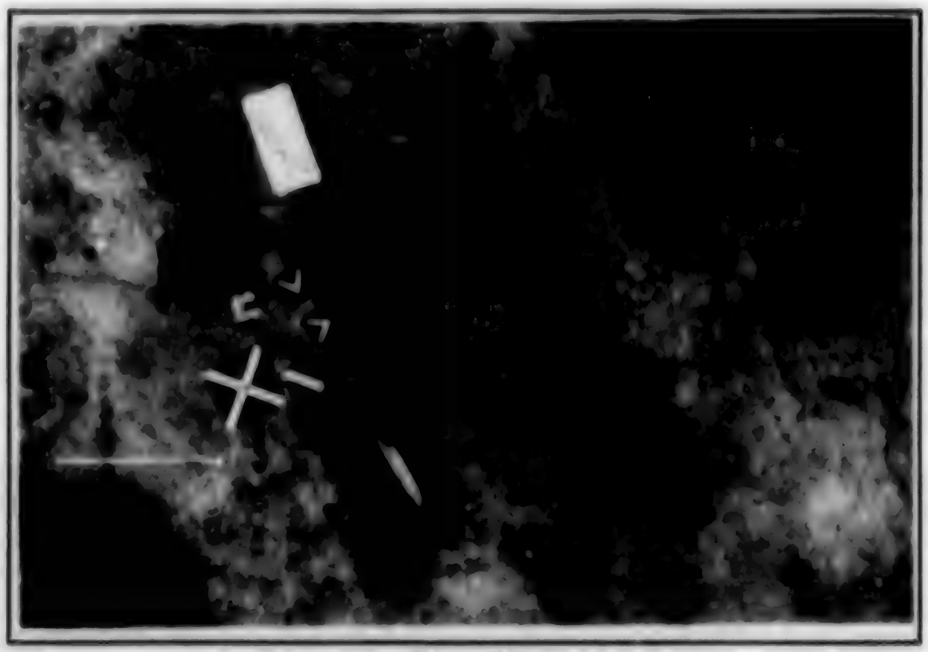

Figure 8.7
Photograph of the Test Target Area During the First Flight of the UU-2 Aircraft

Figure 8.8
Image of a Lava Dike at the North End of Capitol Reef National Monument

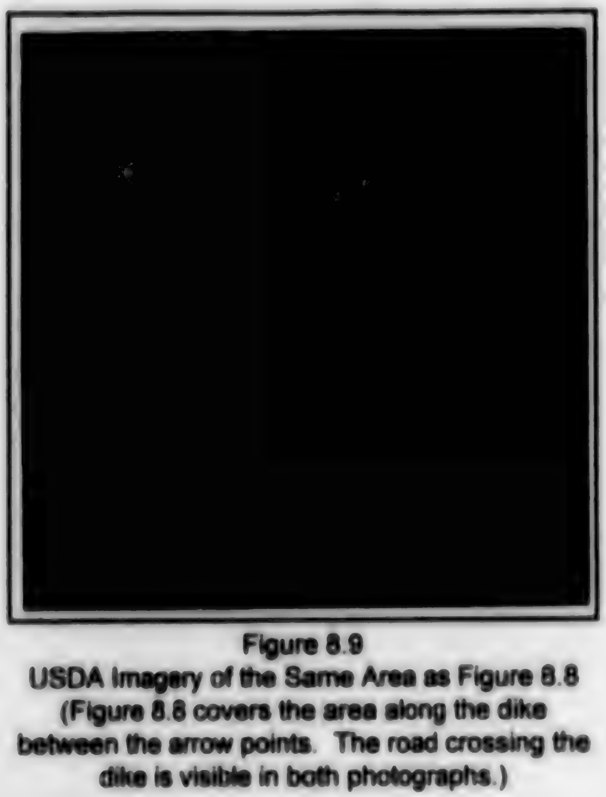

Figure 8.9
USDA Imagery of the Same Area as Figure 8.8
(Figure 8.8 covers the area along the dike
between the arrow points. The road crossing the
dike is visible in both photographs.)

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CAMERA SWITCHING SYSTEM

CHAPTER 9

Many people take care to design mounts to isolate their camera from vibrations in their aircraft, and then reintroduce vibration by using rigid linkages. Most of the camera systems I have seen in radio control model aircraft are mechanically triggered by a rod of some type, which puts pressure on the shutter release. This mechanical linkage carries vibration through the control system and on into the camera. These rods sometimes develop their own harmonics, which further add to the vibration problem. Vibration of any magnitude in a camera will degrade the image.

If a camera is properly mounted and isolated, it should be able to record (resolve) a one-inch width at an altitude of 500 feet. This is near the grain limits of film and the optical limits of most 35 mm cameras. It also means that 20-diameter enlargements should be possible from your Kodachrome and Kodacolor negatives – 20" x 30" prints via Kodak's Poster Print Program can be beautiful and blur-free.

The solution to mechanical linkage systems is provided by an electronic trigger. A small, soft coax cable will transfer considerably less vibration than most other devices. A coax cable has little rigidity, and most of its bulk is shock-absorbing. Every day, more and more autowind cameras are being fitted for electrical cable releases, and a good camera repairman can modify most earlier models at minimal cost.

Making an electronic trigger is quite easy, although both the camera and R/C circuits must be isolated. Initial tests with cameras caused some nasty induction spikes which affected both the cameras and the servos. With our present circuit we have not had a failure or glitch with cameras, servos, or radio systems.

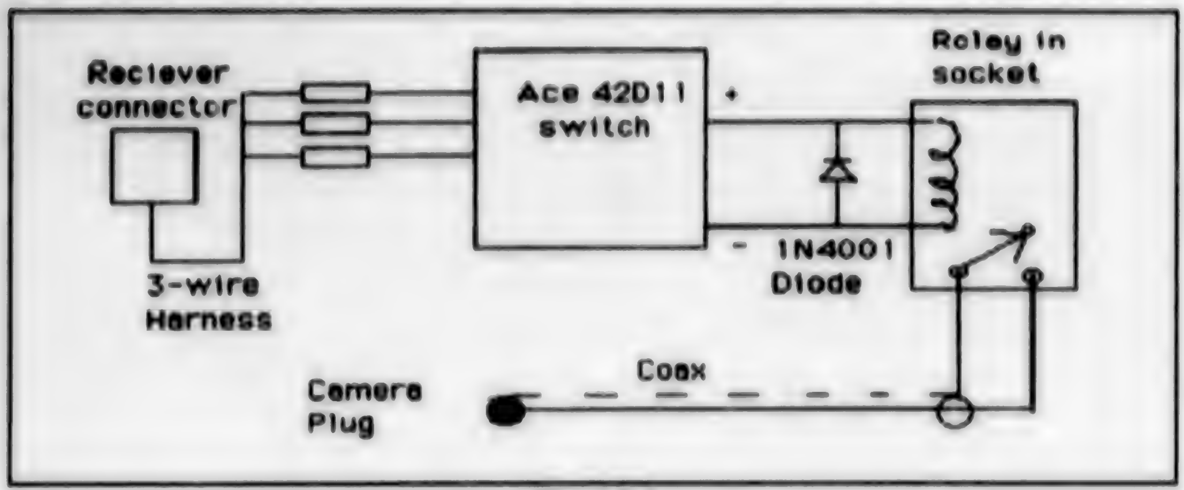


Figure 9.1
Trigger Circuit Diagram

The circuit schematic and construction procedure is outlined in Figure 9.1. To construct the radio-operated switch, do the following;

1. Slide a 1/2" piece of small-diameter shrink tubing onto each of the wires on the Ace switch.
2. Solder the three wires on the wire harness to their corresponding color wires on the Ace switch--red to red, black to black, etc. Slide the shrink tubing over the solder joints and shrink into position.
3. Solder the two output wires to the relay socket pins that will connect to the relay coil.
4. Solder a piece of coax the appropriate length to the mini-plug and to the normally open (n.o.) pins of the relay socket.
5. Solder the 1N4001 diode (as shown in the diagram) between the two socket pins that connect to the Ace switch.
6. Place the relay in its socket and slide a piece of large-diameter shrink tubing over the two components (switch and relay). Test-check the circuit and then shrink the tubing down. There should be a place on both ends to grip the wire as it passes out of the tubing to prevent stress loads on the solder joints.

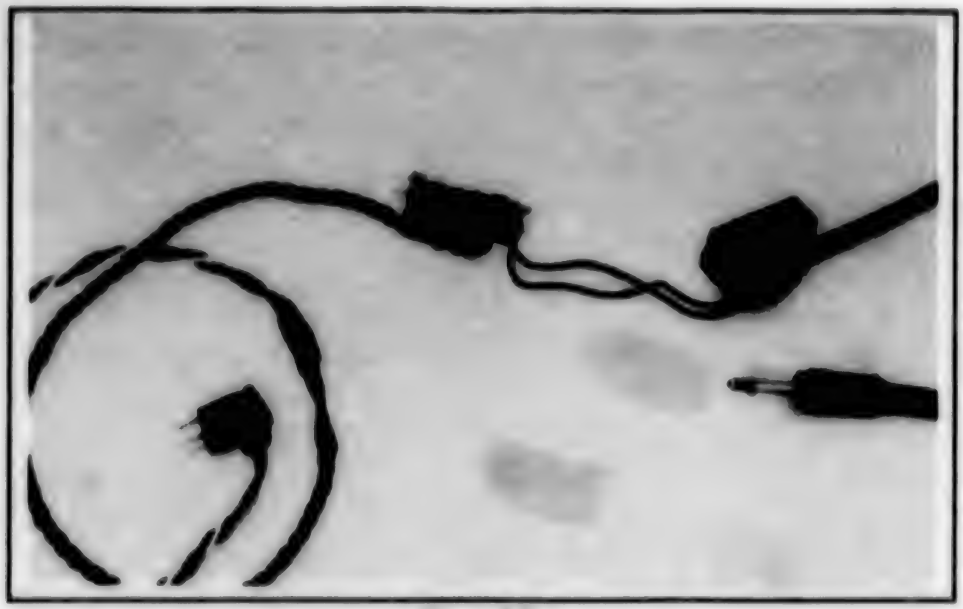


Figure 9.2
Completed Trigger System

To test the circuit, plug the harness into the receiver (Channel 5) and the mini-plug into the camera. Turn the radios on, open the lens cover of the camera, and flip the gear retract switch. The camera should operate each time the switch is operated through a cycle. Our transmitters have had the retract switch removed and a mini-SPDT momentary switch put in its place. The word "gear" as used in this book means "camera gear."

Brigham Young University has been using a Ricoh FF-90 Super-D and a Ricoh KR-30SP for its aerial photographs. They have been very reliable despite the beating from the environment in which we work. Sometimes a tree has been the best landing field. The trigger system has also been tested on Hasselblad, Olympus, and Konica cameras.

For those who use auto-focus cameras, such as the Ricoh FF-90 Super-D, a piece of black tape over the front of the viewfinder or autofocus device usually sets the focus at infinity. The motion of the ground, even as far away as 400 feet, will sometimes confuse the auto-focus mechanism and cause focus problems. The tape helps avoid this problem.

The following items were used in the circuit construction:

Wire harness and connector to fit your receiver
Ace 14G10 switch
Radio Shack relay 5V #275-243
Radio Shack 14 -pin socket #276-1999
Radio Shack diode 1N4001 #276-1101
Radio Shack mini plug #274-289
Radio Shack shrink tubing package #278-1627

8-inch length of small soft coax cable to fit the mini plug
Two short lengths of lightweight insulated hookup wire
Radio Shack SPDT momentary switch #275-619.

The last item is needed only if you want to modify your transmitter for easier operation. (This chapter was originally published in the *Radio Control Modeler Magazine* vol. 25, No. 7, July, 1988. Authors were Eric Adams and James W. Walker.)

FLYING AND FLIGHT TRAINING

CHAPTER 10

Information about flight training is available from the *Radio Control Modeler* magazine's *The Flight Training Course*, (Volume I). Although it is very detailed, it is a great instruction manual. My training came from this book and from some of the local model club flyers who were willing to share their talents. If you can get someone who is experienced to help you, you'll more easily master the basics of flying

Because of the uniqueness of this type of flying (i.e. LALSR), there are some unusual situations and pitfalls to watch to avoid.

A. Speed

Most radio control flyers start slow (that's good) and increase velocity (that may not be too good) as skills improve. Remember, flying for LALSR should be as slow as possible. The slower you fly, the less you need to worry about image motion problems (IMP). Learn the appearance of the aircraft just before it stalls and how to maintain minimum velocity in straight and level flight.

B. Power

Every good RC flyer seems to feel that using the largest powerplant possible is the best approach to flying, but that is not true in this case. Excess power means lower engine rpm during straight and level flight. This in turn creates an aerodynamic vibration in the camera mount as the air flows along the side of the aircraft. This vibration is difficult to control and has been a problem, especially for those who put a .25 or .35 engine on their Butterfly aircraft. The larger engines fly great, but the vibration makes the camera unusable.

C. Flying

Do not perform stunts with the aircraft when the camera on board. The mounts were designed to carry the cameras with plenty of safety margin for normal flight, but not for violent maneuvering. A couple of pilots have pushed cameras through the floor of a Telemaster by performing tight loops after flying a photo line. Wing spars also have their limit when high G-loads are placed on them and the camera weight adds to this load.

Visual crossover (the ability to control aircraft equally well whether it is flying toward or away from you) is perhaps the most difficult part of learning to fly remote-piloted vehicles, and licensed pilots seem to have more difficulty than others in overcoming this problem. One pilot described it as "flying the aircraft instead of the control box." Another described it as "mastery of self-discipline."

Once you have mastered visual crossover, it is time to start practicing straight and level flight toward yourself into the wind (Figure 10.1). This sounds simple, and after quite a bit of practice it is. While practicing, you get a better feel for wind direction, how to turn short angles and relevel the wings fast, how to hold altitude, and how to be patient. Flying into the wind reduces the IMP, because the forward velocity with respect to the ground is reduced. To make small-angle turns, use a short, choppy movement of the rudder and then level the wings either with ailerons or by holding the opposite rudder until the wings relevel. To fly at a certain altitude, you must first learn to measure it and then control it with the throttle.

D. Altitude Measurement

Standard barometric altimeters are accurate within twenty feet. At 5,000 feet this is an 0.8 percent error, but at 200 feet, it is a twenty percent error; you need a more accurate method when you fly at low altitude. Measuring altitude visually can be quite accurate, and it costs nothing. Start out on a football field with a pair of glasses and a roll of narrow-width, printed circuit tape. Place a single strip of tape vertically down the center of one lens, and place the aircraft on the goal line, with the wings parallel to that line. At five feet past the second 35-yard line (200 feet away), while looking back at the airplane through the glasses, place a second piece of tape on the glasses so that one-half of the wing is between the two tapes. This corresponds to the aircraft being 200 feet away; when the full wingspan is between the tapes, it is 400 feet away. When you stand at the opposite goal line, the aircraft is then 300 feet away. If a tape is placed on the other side of the first tape so that the space covers half the wing, you then have 300- and 600-foot markers (Figure 10.2). When the aircraft is flying directly overhead, these three lines of tape make it possible to estimate the altitude by watching the aircraft fly down the tape lines.

For example, the last flight line flown before this writing was estimated at 400 feet using this method; the actual altitude was 415 feet. The previous flight was estimated at over 300 feet; its actual altitude was 330 feet. Actual altitude measurements are taken from the film after the flight. One-meter targets, placed on the ground before the flight begins, are photographed during the flight, and finally their length is measured on the film after it is processed. The ratio of the target size to its film measurement multiplied by the camera lens focal length is the altitude of the aircraft during the time of exposure (This is further discussed in the chapter on image math, surveying, and plotting.).

Another example of the usefulness of this type of measurement occurs during flight when the aircraft is turned onto the flight line and flown toward the pilot. At about 45 degrees up and out in front of the pilot, if it appears to be 550-600 feet on the scale (Figure 10.3) set up by the tapes, then it should appear 400 feet between the tape markers when directly overhead (Figure 10.4.).

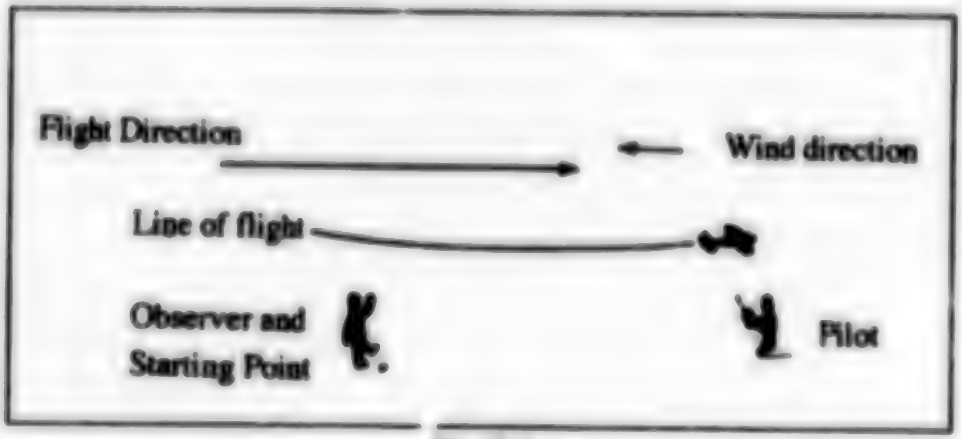


Fig. 10.1
Flying Photo Lines

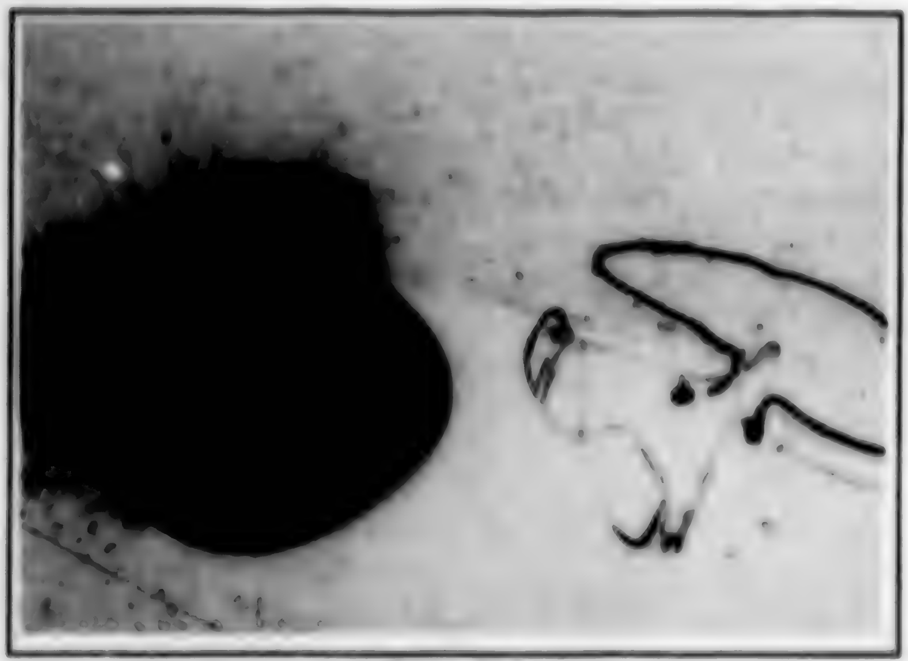


Figure 10.2
Eye Glasses and Corduroy Cap (photo)

After flying a great deal, we discovered an optional way to measure altitude: I started counting the number of ribs on the bill of my corduroy cap. This works quite well, but like eyeglasses, it must be calibrated for each individual's eye and recalibratud after the cap is laundered. If you choose to use the eyeglasses method, *do not drive with the tape on your glasses*. It can destroy your depth perception and hinder your driving capability.

We have learned that to hold altitude for LALSR, it is best to trim the aircraft for speed with the elevator and then set the rate of climb with the throttle. Practice flying parallel to the horizon and setting the throttle until the aircraft maintains level flight. With skill it is not always necessary to retrim for each flight, altitude, or temperature changes. In mountainous areas, the bottom of a temperature inversion makes a good horizon to practice level flight.

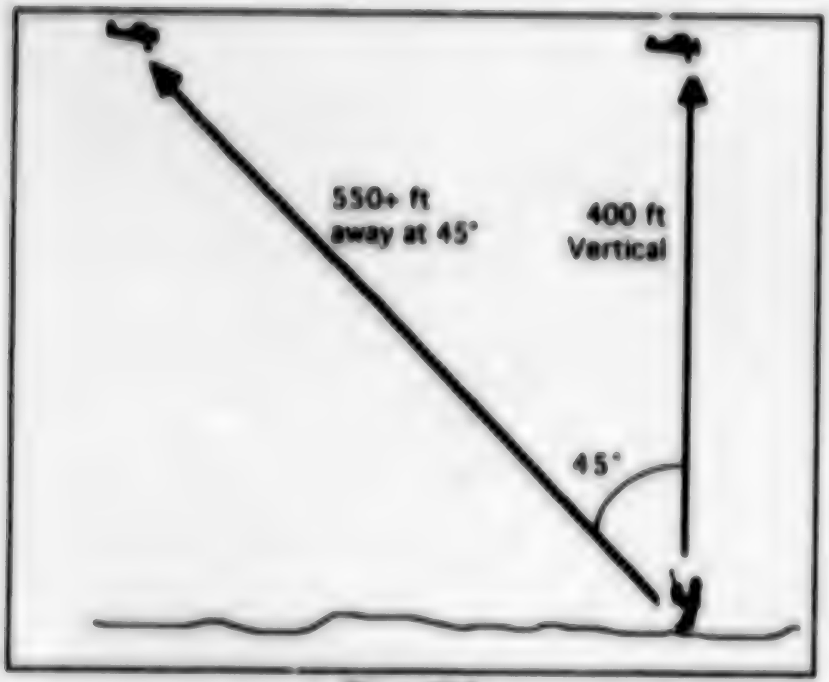


Figure 10.3
45° Diagram

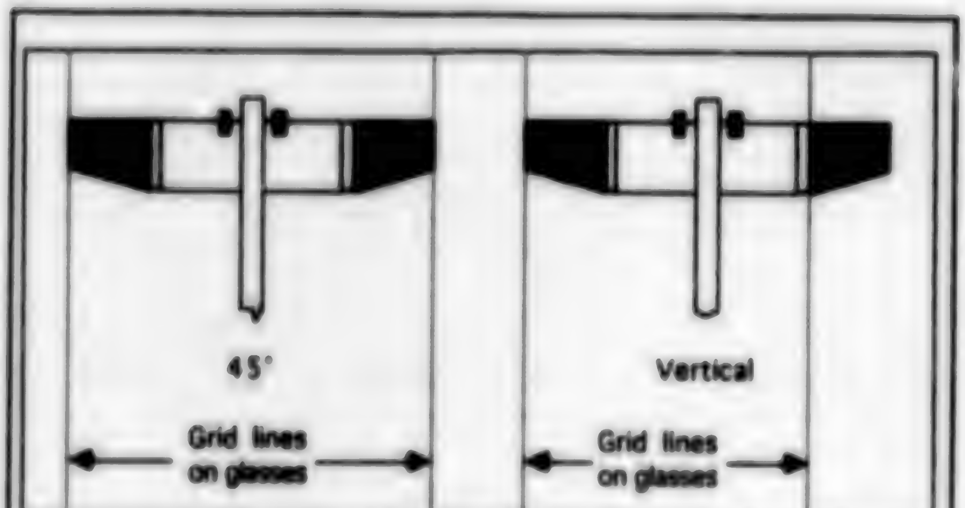


Figure 10.4
Grid View

E. Flying with Weight

While practicing, make other changes such as adding weights and learning to hand launch. It is necessary to hand-launch the Butterfly when the camera is on board, so practice hand-launching--straight into the wind, and level (Figures 3.1 and 3.2). Start taping lead weights (Figure 10.5) on the bottom of the aircraft with duct or gaffer's tape at the center of gravity. Remember, changing the center of gravity of the aircraft invites destruction. The Butterfly should be able to carry eighteen ounces; the Telemaster has been hand launched with 45 ounces of extra weight at 6,000 feet above sea level. If net landing is necessary, practice landing that way.

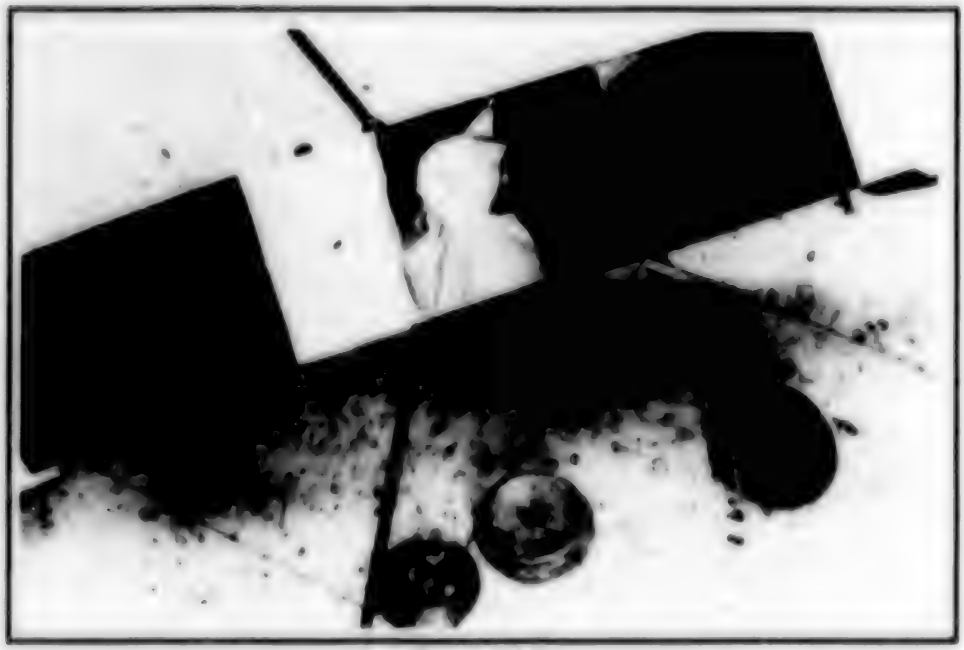


Figure 10.5
Weights on Aircraft

F. Camera on Board

For the first picture flight, load the camera, hook it up (remember the checklist), and launch the aircraft. Once the desired altitude has been reached, check it with a single pass and then place yourself at the upwind end of the target (Figure 10.1). Fly the aircraft toward yourself and trigger the camera when it appears overhead. It's not really directly overhead, so make a second exposure three to five seconds later. If you want to fly a line of photos, then get an observer to stand off to the side at right angles to the flight line and at the starting point. As the aircraft passes the starting point, have the observer signal in some way. When the starting point or observer is not visible, portable Vox radios can be used for communicating. Trigger the camera at proper time intervals to obtain the desired overlap--20 - 30 percent is sufficient for uncontrolled mosaics (Figure 10.6), and 60 percent is required for stereo pairs and plotting. (Mathematics and plotting are discussed in detail later.)

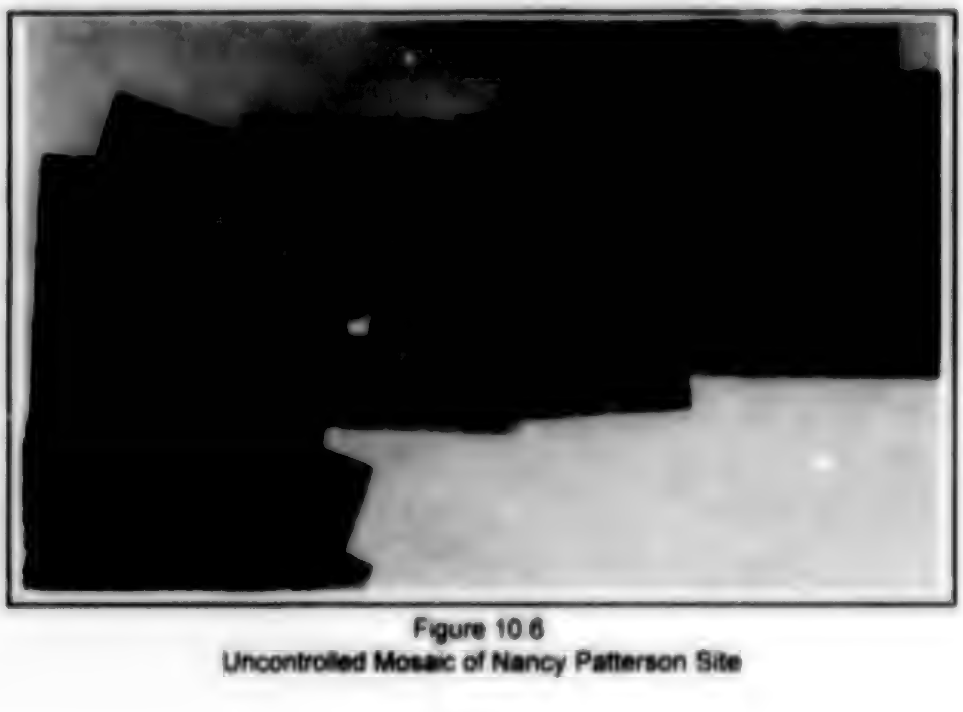


Figure 10.6
Uncontrolled Mosaic of Nancy Patterson Site

G. Landing

The main object of landing is to retrieve of the camera and film for processing. If you're fortunate enough to have a runway, all you have to do is bring the aircraft in low over the approach end of the runway and shut off the throttle. Tall grass and trees with lots of foliage on them are also good landing sites. Those involved in archaeology, agriculture, and geology rarely have good landing space, and when they do, it usually varies in color from the adjacent surroundings, thus causing the air to flow outward and move the aircraft with it (Figure 10.8). (These meteorological conditions will be discussed later.) When landing conditions are rough, sometimes a net works best (Figure 3.4). The approach to the net is as low as possible and just slightly faster than a normal landing approach to assure good rudder control. As soon as the aircraft hits the net, those holding the support poles lay them down on the ground in the direction the aircraft was flying. Figure 3.4 illustrates a net fifteen-feet square tied between two eight-foot lengths of 3/4" PVC pipe. The net excess on the ground is spread in the direction from which the aircraft was making the approach. When making net approaches, practice in a place with enough room before you fly in close, difficult situations.

A tree landing (Figure 3.3) should be as slow and as close to the ground as possible and in the softest part of the tree (where the most foliage is). Lack of foliage penetration can cause more damage (usually to the tail) than the little bit of cover tearing that may take place. Tree landings normally do so little damage that as many as four consecutive flights have taken place in an hour's time with a tree landing between each flight. A soft grass landing approach is in most cases no different from a regular runway approach. A good way to solve landing problems is to decide before launching where and how you're going to land.

H. Meteorology (Macro and Micro)

Since LALSR is a clear-weather activity, there is little need to study meteorology on a large scale except to determine whether you will be flying the next day. The LALSR aircraft's proximity to the earth's surface, along with light wing loading, introduces a series of new situations associated with macro and micrometeorology. Perhaps the best known and most dangerous of these situations is a dust devil. Some dust devils are not visible because they have not yet picked up debris or because the sun angle is deceptive, but when a small, lightly loaded aircraft flies into one on landing approach, recovery is difficult.

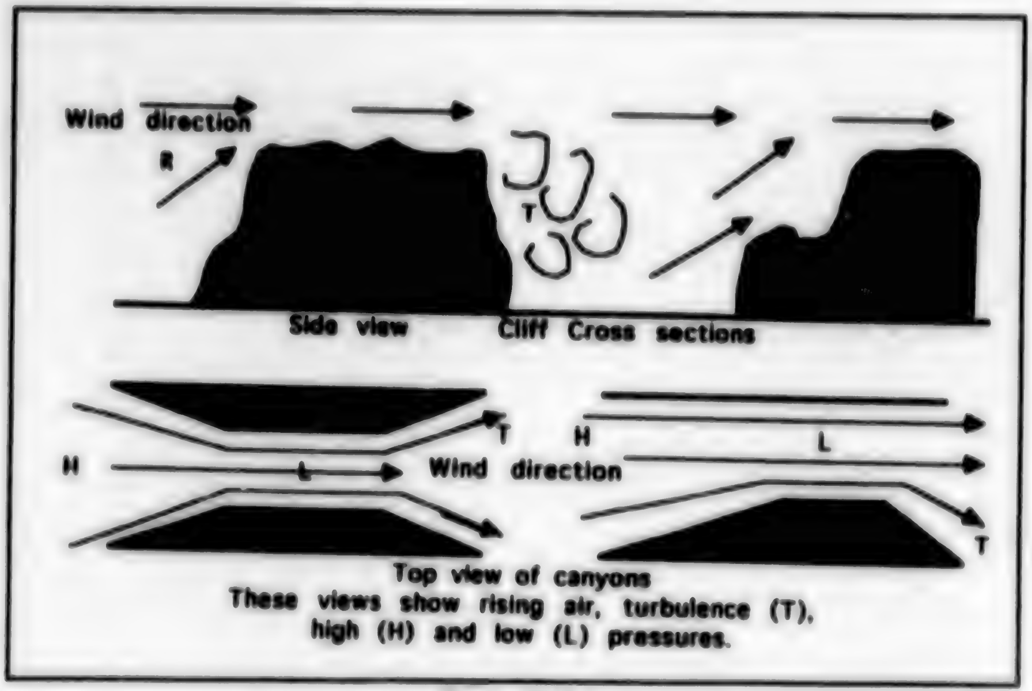


Figure 10.7
Macrometeorological Conditions I

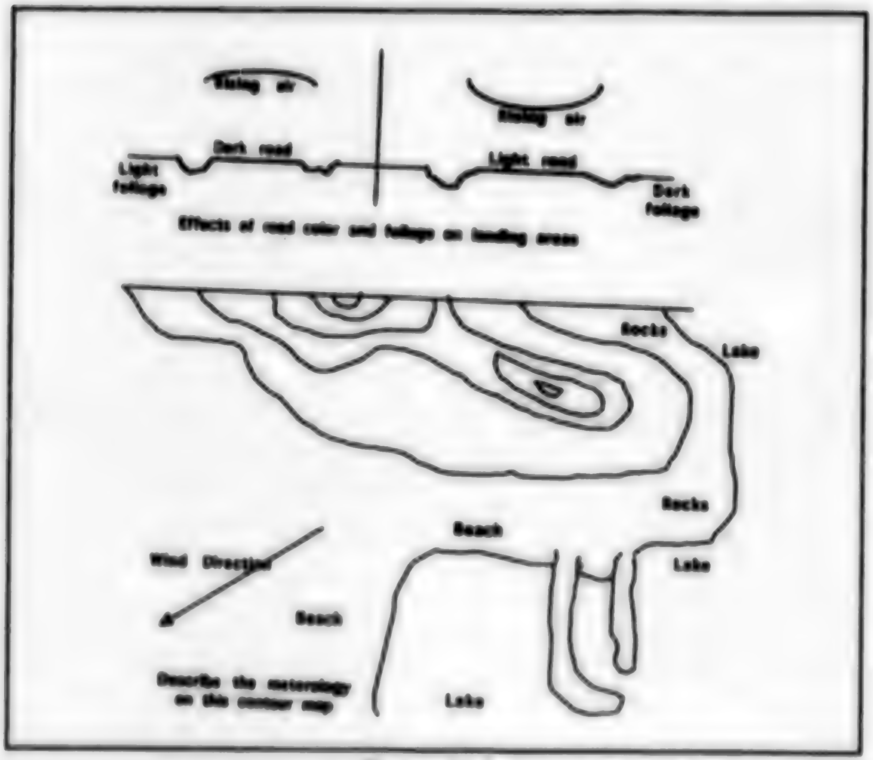


Figure 10.8
Macrometeorological Conditions II

The four basic controls of micrometeorology along with their causes, are these:

1. Bare surface characteristics
    a. wind patterns
    b. soil and air temperatures
    c. humidity
2. Topography
    a. slopes
    b. depressions and knolls
3. Vegetation
    a. tall
    b. medium height
    c. low-growing
4. Constructions
    a. fences
    b. buildings.

Figures 10.7 and 10.8 are typical examples of situations that can be experienced during low altitude flight as a result of micrometeorological conditions. Landing on a light-colored road with dark foliage on either side is much easier than landing on a dark-colored road with light soil on either side. Figure 10.8 shows what the wing will feel in terms of airflow in these situations. Crossing from light to dark areas or vice versa causes the aircraft to bounce up or down, depending on the color change of the surface.

Air currents rise on the windward side of a hill, causing a small aircraft to rise. On the leeward (downwind) side of a hill, air can be turbulent and cause the aircraft to bounce up and down. Because of this turbulence, lift can also be reduced.

At low altitude there is a point along the interface between water and land where the air produces a bump, whose magnitude depends on the humidity and temperature at the land-water interface.

When launching or climbing in a narrow canyon, stay upwind as far as possible from the canyon's narrow points and keep to the canyon's sunny side. Once you are above the canyon rim, fly on the windward and the hot side of the canyon. Avoid turbulent areas.

Active (green) tall vegetation is violent. If you have to climb up between two stands of tall timber, increase the rudder throw on your aircraft and stay exactly between the two stands. Also remember that the interface between a meadow and a tall timber stand is violent.

Do not attempt to land near large signboards or snow fences--these indicate unusual wind currents.

Most of all, when you arrive in an unfamiliar area, check out the surface characteristics, topography, vegetation, and local constructions. These things can be either beneficial or detrimental.

I. Checklists

Checklists are as important as preflight planning. Both are essential, but they are usually ignored until after the first crash. Nothing is more frustrating than flying an excellent flight with a lens cap on or an intervalometer not properly set. A checklist is simply a logical approach for launching the aircraft, photographing, and landing the aircraft so that the film and camera can be safely retrieved. Every time you make a mistake, review and revise the checklist. Checklists should cover even the obvious, because the obvious is often the most forgotten. A procedural change in mission approach can also mean a checklist change. Typical checklists are outlined below. These checklists can be duplicated or cut out and laminated. Once you have completed the checklist, it is time to fly.

Most of all, remember that *safety comes first when flying*. If there is a problem, stop and work it out before you launch the aircraft; that includes finding a landing place, whether in a tree or net, or on a roadway.

BUTTERFLY CHECKLIST

1. Set servos and check all clevis (3)
2. Load camera
3. Mount camera in sponge and mount
4. Plug trigger in camera
5. Top sponge
6. Screw on camera mount (4)
7. Wing (rod, 2 small, 6 large, align)
8. Fuel
9. Range check
10. Battery, starter hookup
11. Prop line
12. Start and adjust engine
13. Open camera door
14. Check wind
15. Launch

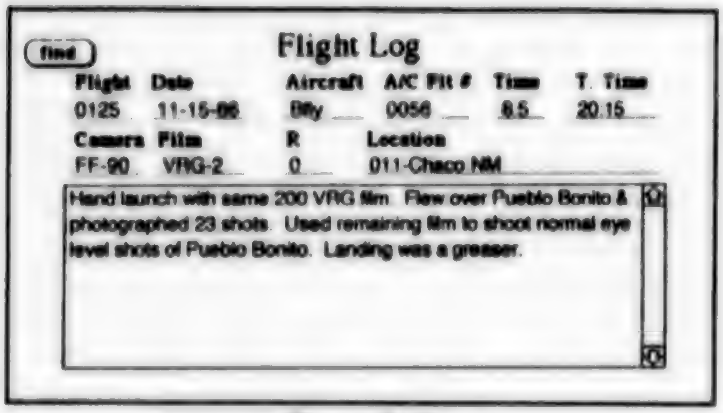
TELEMASTER CHECKLIST

1. Bolt on tail
2. Attach clevis (2)
3. Set servos
4. Load camera
5. Mount in sponge
6. Hook up trigger
7. Turn camera on (2)
8. Mount camera
9. Hook up ailerons
10. Attach rubber bands (8)
11. Fuel
12. Range check
13. Battery starter hookup
14. Prop line
15. Start and adjust engine
16. Remove lens cap
17. Check wind
18. Launch

Figure 10.9
Sample Checklists

J. Flight Log Records

Keep records of your flights, just in case someone asks a question or needs help. In fact, you may be that someone. In addition to records for billing of reconnaissance services, reconstruction of a flight or an accident investigation may be necessary. Figure 10.11 is a computer-based and designed flight log. There are probably better systems, but this one fit the flight test program as LALSR developed. Along with this computer flight log is a 3 x 5 inch spiral card log that is carried with the pilot and completed on the spot. It records the date, flight number and duration, aircraft type, and location. Other notes are recorded as needed and then transferred to the computer record as soon as possible. When your film is processed and printed, it is much easier to mark it and file by that record. Paperwork is necessary if you expect results from LALSR.



Flight Log

Flight	Date	Aircraft	A/C Flt #	Time	T. Time
0125	11-15-86	Billy	0056	6.5	20:15

Camera	Film	R	Location
FF-90	VRG-2	0	011-Chaco NM

Hand launch with same 200 VRG film. Flew over Pueblo Bonito & photographed 23 shots. Used remaining film to shoot normal eye level shots of Pueblo Bonito. Landing was a greaser.

Figure 10.10
Typical Flight Log (log 20)

PART 3. PRACTICAL CONSIDERATIONS

THE IMAGE MOTION PROBLEM

CHAPTER 11

A. IMP

In LALSR, the "image motion problem" (IMP) is measured in inches and causes resolution problems. This measurement is the distance the aircraft moves while the shutter is open. The resolution of the flying reconnaissance system cannot exceed the IMP measurement because it is the amount of blur that occurs while the shutter is open. For instance, at 120 miles per hour, an aircraft moves 2,112 inches in one second; at 12 mph it moves 211.2 inches. If the camera shutter speed is 1/400 second, then the aircraft moves 5.28 and 0.528 inches respectively while the shutter is open. Recognition of any feature on the ground is, therefore, limited to that number of inches moved by the aircraft during the camera exposure. Features smaller than this image motion are distorted in terms of texture, shape, size, and contrast. With LALSR, the IMP is a feature-recognition unit (FRU) of minimum size.

B. Film and Camera Effects on IMP

The Butterfly aircraft weighs less than 84 ounces with camera, film, and fuel. The camera (11 ounces) automatically operates on the basis of exposure value (EV) input. The film speed, combined with the measured available light produces this exposure value (EV), which in turn sets the f-stop and shutter speed in the camera. Most modern, fully automatic cameras operate on this same basic EV system concept. This camera (a Ricoh FF-90 Super D*) has a maximum shutter speed of 1/400 second, is obtained at an EV of 16 or higher. The reading from an incident light meter on an average clear-weather, sunny day, indicates a film speed of ISO 200 is needed to obtain this EV and thus the maximum shutter speed possible. As a result, most tests and uses of this equipment have been with ISO 200 film. This produces maximum shutter speed and consequently minimum IMP.

Film used in LALSR is ISO-rated, rather than aerial film speeds. This is because of the film availability in 35mm format and the haze problem. Many films available in 35mm format are not available in other sizes. Most of these films are ISO-rated. At least ten different types of film have been successfully tested and used in the ISO 200 range.

Haze is near nonexistent at the altitude flown with LALSR. Even most haze-causing temperature inversions are above 600 feet, and 600 feet above the ground is about the highest altitude for safe LALSR operation. However, where contrast control is needed, placing a piece of masking tape over the film cassette data block before loading the film into the camera allows film speed control for this specially required processing.

Film	Type	Speed (ISO)	Resolution l/mm
T-Max	Black and White	200	200
Plus-X Pan	Black and White	200	125
T-Max 400	Black and White	400	125
Vericolor Gold 200	Color Negative	200	100
Fuji 200	Color Negative	200	100
Kodachrome 200	Color Positive	200	100
Ektachrome 200	Color Positive	200	100
Fuji 200	Color Positive	200	100
Ektachrome Infrared	Color Positive	N/A	63

Figure 11.1
Films Most Commonly Used with LALSR

C. System Resolution

The resolution of the system mounted in the aircraft is affected by the lens, film, and powerplant vibration. The total effect of these factors can be determined by a quick and simple method that has proven relatively accurate.

With the camera mounted in the aircraft and the powerplant operating at cruising rpm, the aircraft is suspended so that the lens is 26 focal lengths from National Bureau of Standards targets parallel to the lens and then the targets are photographed. Using this method, exposures that show 80 lines per millimeter resolution have been made, processed, and read. Figure 11.3 is a verification of this type of test during a flight (this will be discussed later).

The image recorded during a flight is a function of both the system resolution and the IMP. To obtain optimum feature definition, the photo scale should be such that the IMP at ground level equals the system resolution on the film. As an example, if the system resolution is 75 lines per millimeter (0.01333 mm) and the IMP is 0.528 inches (13.41 mm), then the optimum scale is 13.41 / 0.01333, or 1:1000. (All numbers in parentheses are given to maintain proper dimensional relationships.) To obtain a scale of 1:1000 with a 35mm (0.2248 ft) focal length lens, the camera in the aircraft needs to be 115 feet above the ground. This altitude is determined by use of the following procedure.

Scale is the ratio of image to object size. The altitude at which the mission is flown for a particular scale is obtained by multiplying the scale reciprocal by the focal length of the camera lens. For this particular situation, flying below this altitude records excess blur on the film, and flying significantly above that altitude does not fully take advantage of the capabilities of the camera film system. Scale determination will, therefore, fit within an envelope on an object-image plot of various scales (Figure 11.4).

Superimposed over these graphs, the system resolution and the IMP define the operation envelope for each of the two LALSR aircraft that are being used. Reconnaissance systems do not work well outside their envelopes, and these envelopes are limited on the image side by system resolution and on the object side by the IMP. For example, flying with a Butterfly aircraft at a scale of 1:600 (altitude 69 feet) still limits the system's resolution to 22 micrometers because of the image motion (Figure 11.4). Photographing objects smaller than the system resolution is not possible. On the graph, therefore, the same scale must be above the IMP limit and to the right of the system resolution limit (Figures 11.4).

D. The Aircraft

Two model aircraft have been used for LALSR. Purchased from a model shop, they are off-the-shelf kits which have been built according to the manufacturers' instructions. Camera addition and modification came after the aircraft was initially flown and trimmed. The parameters of these aircraft have been calculated and tested; the results are shown in Figure 11.2.

		AIRCRAFT	
PARAMETER	BUTTERFLY	TELEMASTER	UU-2
Speed (radar and image)	12 mph	12 mph	12 mph
Camera Ricoh	FF-90	Ricoh KR-30	Ricoh KR-10
Lens Focal Length	35mm	50mm	50mm
Operating shutter	1/400 sec	1/1000 sec	1/1000 sec
Shutter open interval	0.0025 sec	0.001 sec	0.001 sec
IMP (minimum feature recognition unit)	0.528 inches	0.210 inches	0.210 inches
System Resolution	75 lines/mm	80 lines/mm	80 lines/mm
Image recognition size	13.3 micro-mtr	12.5 micro-mtr	12.5
Optimum scale(altitude)	1:1000 (115 ft)	1:400 (71 ft)	1:400 (71 ft)

Figure 11.2
LALSR Aircraft Parameters

Sufficient data exist to indicate the need for a camera with a 1/1000 second shutter speed and a weight of less than 360 grams (12.5 ounces) to fit the Butterfly. Both aircraft work equally well, but the Butterfly's portability makes it a better choice when flying from remote operating sites.

E. Actual and Calculated IMP

Calculations predict the images that can be recorded, but actual flight data must be obtained for verification. Figures 11.3, 11.5, and 11.6 were obtained from actual test flights. Figure 11.3 was made with the Telemaster aircraft at 78 feet. The unpainted chaining pins used to hold down the colored cloth targets are visible, as are their shadows. The diameter of these pins is 0.20 inches, which is very close to the IMP. If the resolution appears slightly better than calculated, it could be for two reasons: either the aircraft was flying into a slight headwind, which was not measurable, or the system resolution may not be as good on the test stand as it is in flight because of test mount problems.

Figures 11.5 and 11.6 were made during a Butterfly flight over the same target at altitudes of 63 feet (Figure 11.5) and 120 feet (Figure 11.6). Object detail on both original photographs is the same. This verifies the idea of working within an envelope prescribed by the object-image plot. Ground resolution of these exposures is between 0.5 and 0.6 inches. One flight was into the wind (Figure 11.5); one was with the wind (Figure 11.6). Again, the wind was discernible but not measurable.

Figure 11.3
Aerial Photograph (original in color)
Exposed at 78 foot Altitude with Telemaster
Aircraft, 1/1000 Second Shutter Speed
(Chaining Pins and their Shadows are Visible)

Little has been said about image motion due to roll rate. This is because of lens focal length and film width. For instance, with a 50mm (2-inch) lens used with LALSR, image motion factors pertinent to roll rates are 887 radians per second, as compared with 2,660 radians per second with a 6-inch lens used with a regular (9 x 9) aerial camera. Also, image motion at the photo edge is only 1.1 times that at the center because of the narrow film width (25mm vs. 9 inch).

F. Mathematics and IMP

On all aerial photographs there is some image motion due to the forward motion of the aircraft. It is therefore useful to know how much motion there is and how to deal with it mathematically.

Altitude is measured in feet; optics, images, and targets are measured in millimeters and meters. Time is measured in seconds;

velocity is measured in both miles per hour and feet per second. All the numbers in the formulas below are constants for dimensional correctness. Several numbers and formulas also need to be known when image motion is used.

The image motion (IMP) is equal to 17.6 times the aircraft velocity (v) multiplied by the shutter speed (Ss), or

$$IMP = 17.6\ v \times Ss$$

where velocity is measured in miles per hour and the shutter speed is measured in seconds. This means that an aircraft traveling 100 miles per hour with a 1/400 second shutter speed travels 4.4 inches during an exposure. The number of inches moved by an object in one second at one mile per hour is 17.6, and it dimensionally balances the formula.

Scale (Sc) is the image size (Is) to object size (Os) ratio, or

$$Sc = 25.4 \times Is / Os$$

where the image size is in millimeters and the object size is in inches. Optimum scale is reached when the IMP on the ground is equal to the resolution of the camera system. This represents the best capability of the entire system.

Resolution is the smallest object the camera system will record on film. It is measured in lines per millimeter, and its reciprocal is the size of the measured image.

The optimum altitude to fly a reconnaissance mission is at a point where the optimum scale is obtained. This altitude is obtained by multiplying the scale reciprocal (Sr = 1 /Sc) by the focal length (Fl) of the camera lens:

$$\text{Altitude} = Fl \times Sr / 304.8$$

where altitude is in feet and the focal length is in millimeters. For example, with a 100 mph aircraft, 1/400 second shutter speed, 4.4 inch IMP, a system resolution if 80 lines per millimeter (0.0125 mm), and a 50 millimeter camera lens, we have the following optimums:

Optimum scale = 1: 8,940.9 or 1: 9,000

Optimum altitude = 1,449.5 or 1,450 feet.

Therefore, to make IMP calculations, the following are needed:

1. Aircraft velocity
2. Focal length of the camera lens
3. Camera shutter speed
4. System resolution.

For the systems used in LALSR, these parameters are listed in Figure 11.4.

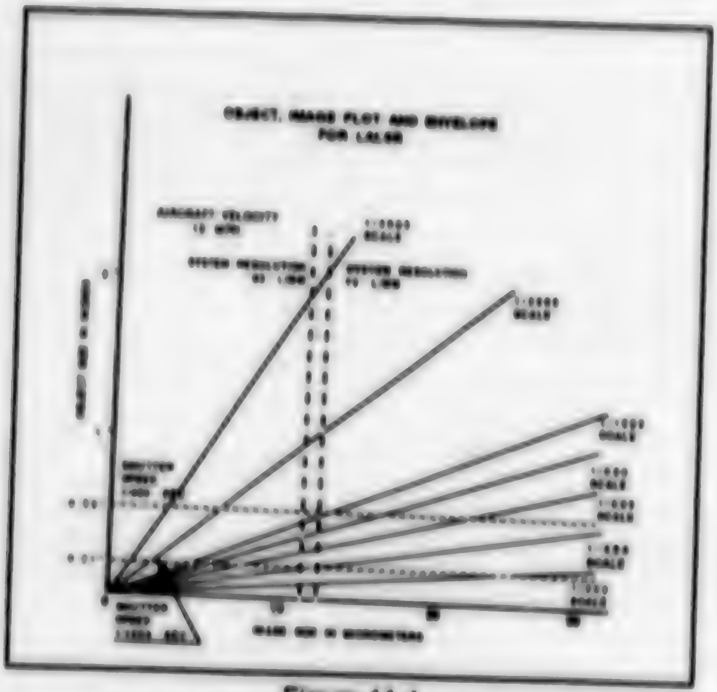


Figure 11.4
Object-image Plot and Envelope

Figure 11.5
Aerial Photograph (original in color)
Exposed at 63 feet Altitude with Butterfly
Aircraft, 1/400 Second Shutter Speed.
(Surface resolution is 0.56 inches.)

Figure 11.6
Aerial Photograph (original in color)
Exposed at 120 feet Altitude with Butterfly
Aircraft, 1/400 Second Shutter Speed.
(Surface resolution is still 0.56 inches.)

G. Summary

It is possible to determine, test, and define parameters in a low-altitude, large-scale reconnaissance system. These parameters are used in mission planning and, where needed, for comparison with other systems. Minimum object size (feature recognition unit) is limited by the IMP; image size is limited by system resolution. These two sizes (object and image) are the limiting factors in a scale envelope that define the altitude at which an aircraft should be flown for obtaining maximum results. These parameters are outlined in Figure 11.4.

IMAGE MATHEMATICS

CHAPTER 12

Several useful mathematical expressions and formulas help define LALSR and its related photography. These formulas will help to make most of the calculations needed to obtain information before flying and then extract data from that imagery. Most of these formulas are related to one or more of the following: motion, scale, altitude, coverage, and overlap. Also, most of these formulas are derived from the image motion and scale formulas, so they are listed first in this section.

A. Motion

The distance an aircraft moves during a camera exposure is the image motion (IMP). As mentioned, this is measured in inches and is derived by multiplying the velocity of the aircraft by the amount of time the shutter is open. If the velocity is in miles per hour, the shutter speed in seconds, and the result is desired in inches, then the it must be multiplied by 5280 ft per mile, 12 inches per foot, and divided by 60 minutes per hour and 60 seconds per minute:

$$5280 \times 12 / 60 \times 60 = 17.6.$$

The answer, 17.6, is a unit balance factor (ubf). It corrects for dimensions that are in different units of measurement, i.e., focal length in millimeters and altitude in feet. Therefore:

$$\begin{array}{llll} \text{IMP} = & 17.6 & v & Ss \\ \text{in} & \text{ubf} & \text{mph} & \text{sec.} \end{array}$$

The blur (B) this motion (IMP) creates on the film in millimeters is 1.47 multiplied by the velocity in mph, multiplied by the exposure time in seconds, multiplied by the focal length (Fl) of the camera lens in millimeters. This number is then divided by the altitude (Alt) in feet, or

B = 1.47 v Ss Fl / Alt
mm ubf mph sec mm / ft

or

B = 12 IMP Fl / Alt
mm ubf in mm / ft.

Further, when this blur is measurable on the film (when flying below optimum altitude), it is possible to calculate the velocity of the aircraft if the flight line is pretargeted with a one-meter square target. Use the short dimension of the target on the film to measure the altitude and the difference between the short and long dimensions on the target as the blur (B). Then:

v = B Alt / 1.47 Ss Fl.

Figure 12.1 represents the relationship between focal length (Fl), altitude (Alt), object size (Os), and image size (Is). This clarifies the above equation if the object size is considered the IMP and the image size is considered as the blur.

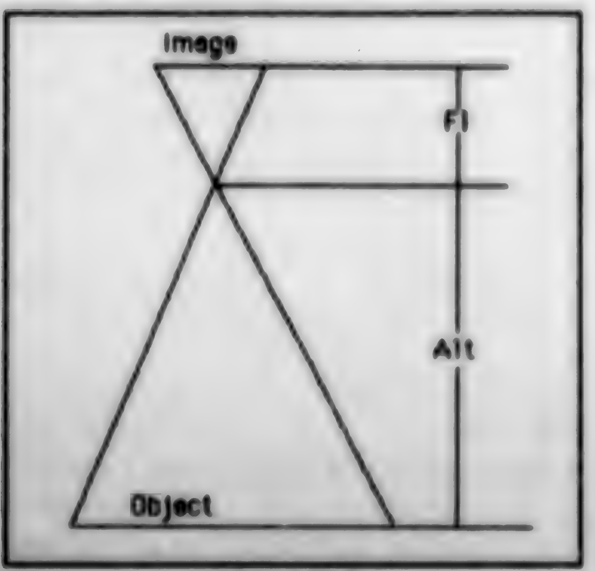


Figure 12.1
Image, Object, Focal Length, and Altitude Relationships

With the camera focused at infinity, the diagram in Figure 12.1 indicates

Alt / Os = Fl / Is

or if dimensioned:

304.8 Alt / Os = Fl / Is
ubf ft /mm mm / mm.

The focal length of a camera lens is fixed, the object size can be measured on the ground, and the image size can be measured on the film; therefore, the flight altitude can be calculated.

B. Scale

Scale is the ratio between a photograph and its full-sized counterpart, or the image-to-object ratio. For example, if a one-meter ground target measures one millimeter on film, then the scale is 1:1000. Therefore:

Sc = Is / Os

or if dimensioned:

Sc = 0.0394 Is / Os
ubf mm in.

Optimum scale is achieved when the image motion (IMP) equals what the camera film system can record (resolution [Rs]):

Sc = 0.0394 Rs / IMP
ubf mm in.

If the scale is the image-to-object ratio, then mathematically it is also the lens focal length (Fl) to altitude (Alt) ratio:

Sc = Fl / Rs.

Some people prefer to use the scale reciprocal instead of the scale because it is a large number instead of a fraction. The scale reciprocal applies to Figure 12.2 which demonstrates how scale relates to image and object size. To use this equation, choose the unknown quantity and perform the mathematical function indicated by the position of the remaining two quantities. If the remaining two quantities are side by side, then multiply; if they are above and below, then divide the top by the bottom. Dimensions involved with this diagram will have to be unit balanced.

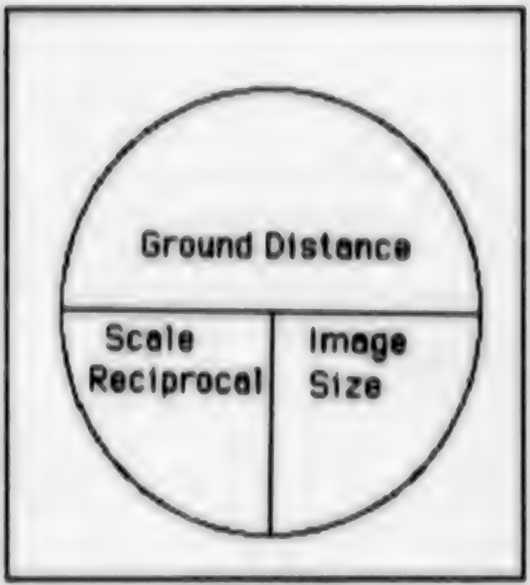


Figure 12.2
Mathematical Circle for Object, Scale, and Image

C. Altitude

Altitude is needed for two purposes with LALSR. To determine the altitude to fly an aircraft for a specified scale:

Alt = Fl Sr

or if dimensioned:

Alt = Fl x Sr x 0.00328
ft mm ubf.

To determine the altitude to fly an aircraft for specific coverage:

Alt = Fl Os /Is

where the object size is the coverage in feet and the image size is the film width in millimeters.

To determine altitude from imagery with the use of a one-meter target:

Alt = 3.28 Fl / Is
ft ubf mm mm.

With a Butterfly and Ricoh's FF-7 series cameras with 35mm focal length lenses:

Alt = 114.8 / Is

and with a single lens reflex camera (SLR) with a 50mm focal length lens:

Alt = 165.1 / Is

If a different sized target is used:

Alt = Fl Os / Is.

The ubf depends on what the object size is measured in (feet, inches, etc.).

D. Coverage

Coverage is the area, length, or width that is covered on the ground by an aerial photograph. It is a function of the camera lens focal length and the altitude of the aircraft, so the preceding equations apply. The object size now becomes the ground coverage width (Fcw) or length (Fcl). The image size becomes 24 or 36 (film width or length in a 35mm camera). Therefore:

Fcw = 24 Alt / Fl and Fcl = 36 Alt / Fl
ft mm ft mm.

E. Overlap

Overlap is needed for two reasons with LALSR: to produce stereo images for stereo viewing and plotting, and to produce a continuous long-strip photograph. The overlap for obtaining stereo photographs must exceed 56%; however, 60% is the amount desired by most cartographers. With 35mm imagery and the direction the format is turned in the aircraft, the overlap is in the long direction of the film (Fcl). For 60% overlap, 0.6 Fcl of one photo must overlap 0.6 Fcl of the next photo. This means that for 60% overlap, the distance the aircraft needs to travel between exposures is 0.4 Fcl, 0.4 (36 Alt / Fl), or 14.4 Alt / Fl.

For LALSR purposes it is perhaps better to calculate overlap in terms of seconds between exposures. It is difficult to measure visually the distance an aircraft has flown from the ground, but one can count or measure the time it takes to cover this distance if the aircraft velocity is known. This time (OI) is obtained by dividing the distance between exposures by the aircraft velocity along the flight line:

OI = 9.82 Alt / (Fl) (v)
sec ubf ft mm mph.

If different percentages of overlap are needed, the equation changes to:

OI = (1 - % overlap as a fraction) 24.54 Alt / (Fl) (v).

For example, if we want 20 percent overlap, then we use 0.8 as the interval by which to multiply the remainder of the equation to get the proper time interval in seconds. Overlap is further discussed in the section on surveying and mission planning.

F. Summary

Nearly all equations are derived from figure 12.1. If others are needed for mission planning or image plotting, you should be able to derive them from this equation if they are related to image, object, lens focal length, or altitude.

MISSION PLANNING, SURVEYING, AND FLYING

CHAPTER 13

A. Flight Planning

Flight planning usually begins with a visit to the area to be photographed and the study of smaller scale aerial photographs. Terrain, wind direction, and meteorology must be considered when setting up flight lines in terms of altitude and direction. Because of LALSR aircraft velocity and altitude, much could be written on micro-meteorology, the effect of topography upon it, and the effect micro-meteorology and topography on slow-speed aircraft performance. In the southwestern United States, for example, many archaeological sites are in narrow canyons, and as the canyon width varies, so do both the wind velocity and the barometric pressure (venturi effect). These in turn affect flight characteristics of the aircraft. Sometimes a premission flight can help determine final flight lines and patterns from a meteorological standpoint.

Flight lines are, in most cases, into the wind. This helps reduce blur. If a north line is needed, a piece of contrasting color cloth or plastic can be temporarily placed on the ground and aligned with the compass. This permits compass alignment on the final photographs. If stereo photographs are being produced for topographic measurement, then time-space intervals between photographs must be calculated and control points surveyed and marked in the area to be photographed. With remote-piloted vehicles, the time-space interval can be operated by the pilot on the ground or with an intervalometer using an NE555 circuit, which weighs about one ounce. Several circuit diagrams are available from those who are manufacturers of that electronic chip.

In altitude estimation, first determine the width to be covered. Plan for a margin of error, especially if you are new at flying straight lines. From this width (Fcw), determine the flight altitude you need to cover that dimension (see chapter 12). Next determine the length of the coverage (Fcl). The overlap for stereo imagery needs to be 60%; in other words, a photo should be exposed each time the aircraft travels 0.4 Fcl. The overlap time should then be calculated on the basis of velocity, and 0.4 Fcl. As you fly down the flight line, trigger on the basis of this time interval if you are sure you are close to the correct altitude. If you are flying into the wind, this will increase your overlap; but remember it is better to have too much overlap than too little. Also remember that you are flying a fair-weather machine; the wind will probably be negligible and even helpful. For accurate altitude determination after the flight, place a cloth control panel (1 meter x 0.5 meter) on the ground in the image area before the flight. At the altitudes flown, both altitude and velocity can be determined from measurements on the processed imagery. Final accuracy of altitude is achieved by measuring the one-meter side of the control panel on the final image. With a 35mm focal length lens:

Altitude = 114.83 / Target image size in mm

and with a 50mm focal length lens:

Altitude = 165.13 / Target image size in mm

B. Targeting

Once the purpose and approach of the mission have been defined, targeting is usually needed on site. Targeting is a ground truth reference designed to fit the situation. The altitude determination from control panels is a good example of how targeting is used. These cloth panels are also used for color matching in the printing process and velocity determination (Figure 13.1). It is relatively simple to take one of these colored cloth panels into a photo printing lab and ask a printer to match it on a print. This gives an idea of actual colors as they exist in the area being photographed. (Velocity measurement with these targets was covered in chapter 12.)

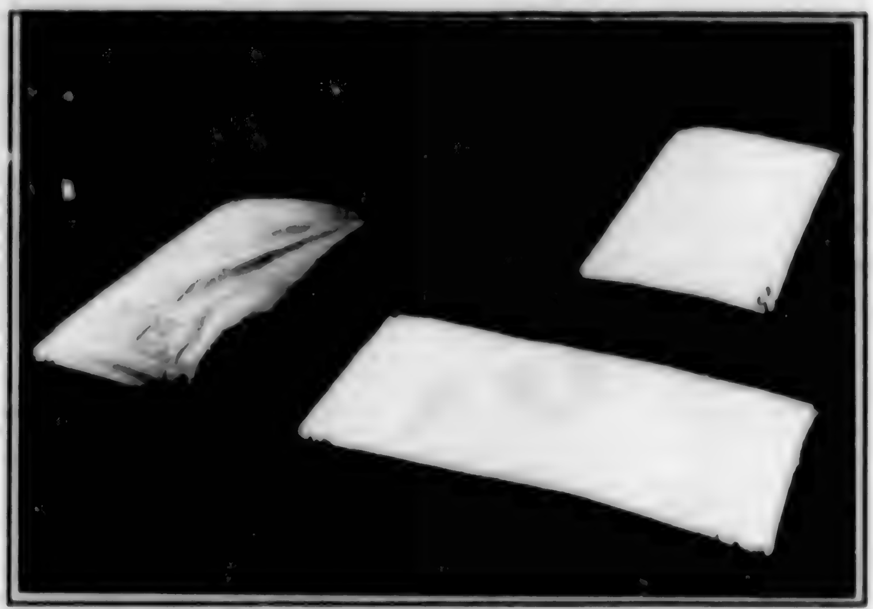


Figure 13.1
One by One-half Meter Cloth Control Panel Targets

With help from Larry Gillen of Packer Engineering, Arthur Ireland of the National Park Service, and others, special 12-inch square targets (Figures 13.2 and 13.3) were designed to use for stereo plotting LALSR imagery. These targets have been photographed at distances of up to 600 feet with visual readability on Kodachrome 200 film. The targets can also be black on white when the background dictates. When targets are placed in position, a large, long spike is driven through the hole in the target as a survey point to be surveyed either before or after the flight. If the terrain is such that a nail cannot be driven, then a can of spray paint can be sprayed into a funnel, which is placed into the nail hole. If flying is completed before the survey, then the nails and paint dots are flagged and the targets are moved to the next flight area. The number and placement of targets should be determined by both the plotter and the surveyor. These 1/8 inch masonite targets can be used on two or three sites in a single day. They do not take up much space, but 42 (1/2 cubic foot) targets weigh quite a bit. When a larger target is needed, turn over four of these targets and arrange them so they will make a large X (Figure 13.4). This works to an altitude of 5000 feet.

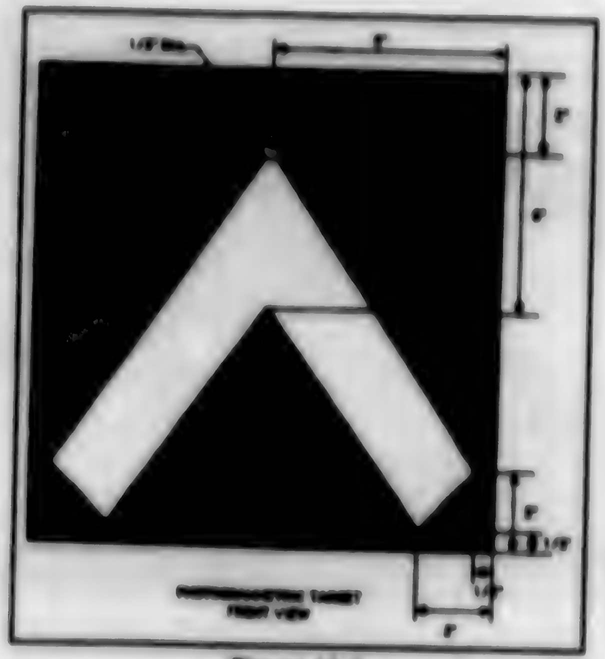


Figure 13.2
Low-Level Stereo Plotting Targets

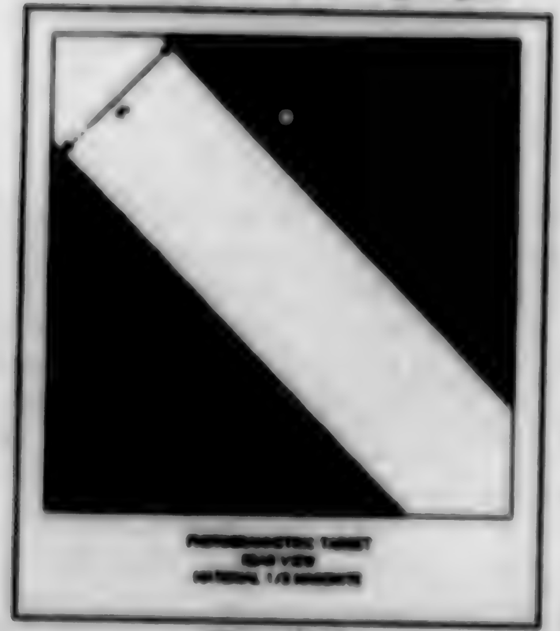


Figure 13.3
Back Side of Plotting Targets

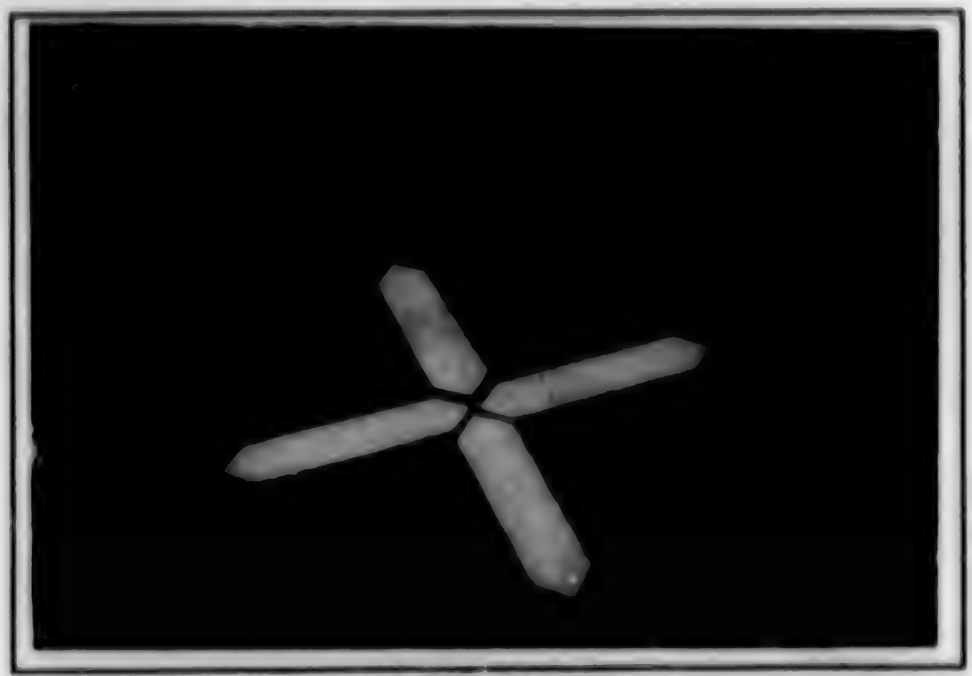


Figure 13.4
Four Plotting Targets Put Together
for Higher Altitude LALSR Stereo Plotting

Sometimes it is necessary to have spatial targets in areas where stereo plotting is being done. This is especially true when there is high vertical rise over short distances. Arthur Ireland designed an elevated ground control target tower specifically for this situation. It is made with PVC pipe, pipe fittings, clamps, and string (Figures 13.5, 13.6, and 13.7).

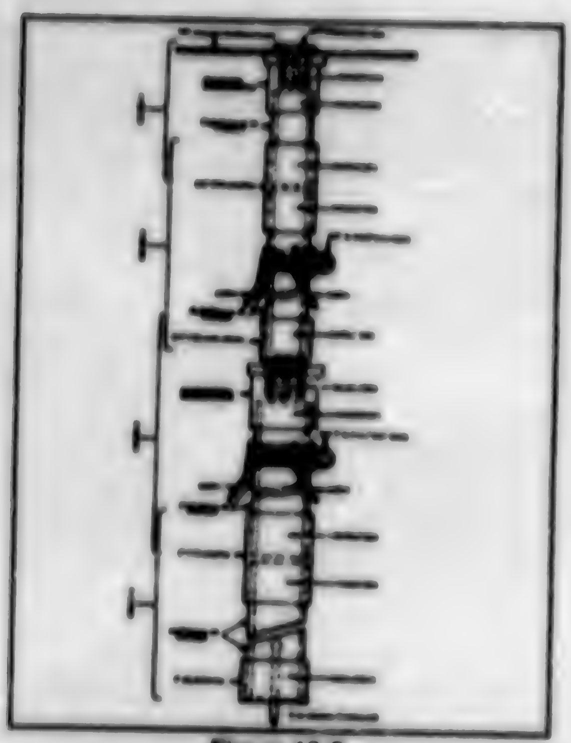


Figure 13.5
Elevated Ground Control Target Tower

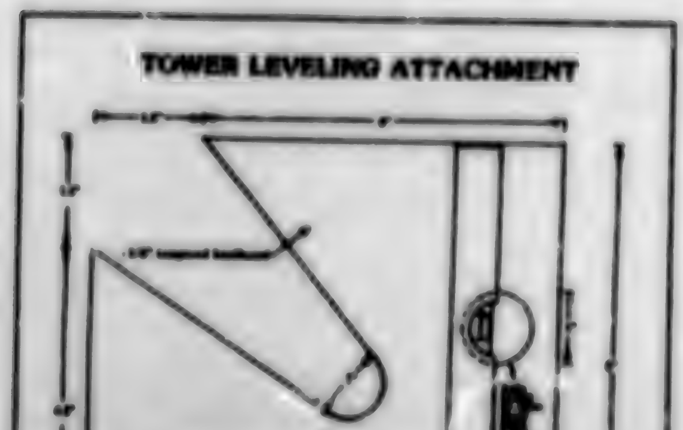


Figure 13.6
Tower Leveling Attachment

Figure 13.7
Photograph of Elevated Tower in Use

Objects such as stream weirs, fence posts, painted highway centerlines, and even cans have been used for targeting where stereo plotting is unnecessary. Be innovative in making the best target for the situation.

C. Surveying

As soon as the pretty effects and the object identification syndrome of LALSR wear off, someone will want to take measurements from the imagery. If proper ground-work (targeting, surveying, and ground truth data) has been done before a flight, then these measurements will be possible. If serious surveying is required, obtain the services of a qualified individual. The type of surveying needed depends on the accuracy required. From the simplest forms to the most accurate, there is an order which indicates that accuracy is related to cost:

1. Pacing
2. Pacing and compass
3. Chaining
4. Plane table
5. Transit or theodolite
6. DME equipment
7. Global positioning satellites (GPS)

What an individual obtains depends on the level of accuracy needed and the funding available. Keep in mind the final product when it comes to analysis of the imagery. This also applies to ground truth work.

D. Ground Truth

Ground truth needs vary according to the discipline. As much as possible, ground truth should be accomplished on site and as close to the flight time as possible. Ground truth for LALSR is usually easy to obtain, because often the aircraft is hand launched on site, allowing both the pilot and a second person to do this work. These two individuals--especially if one is a content specialist--can obtain most of the needed ground truth information while on site. A content specialist is an individual who knows the terrain and has expertise in the particular field for which the reconnaissance is being done. In some fields, for example, temperature, humidity, and soil moisture content are critical to image interpretation. Eye-level photographs also help with initial image interpretation. Count fence posts, measure their direction, measure wall thicknesses, and determine the number of courses of masonry. You may not need all this information, but if it costs no more, having it is cheaper than returning to the area.

E. Film

Although film and its processing will be discussed in more detail later, it needs to be mentioned here since it is part of the mission planning process. Most LALSR imagery is produced at altitudes where haze and temperature inversions are not problems. Because of this, almost any daylight film emulsion can be used. This includes aerial emulsions and offers a greater range of image capability. Most of the present low altitude work is done with 35mm film, which offers a large variety of emulsions from which to choose. Even Kodak Technical Pan, with its fine grain and wide contrast processing range can be used with some of the slow RPVs. In some cases, processing can be accomplished on or near the site. This is ideal, because if a first look at the film indicates a need for additional flights or ground truth, this can be accomplished immediately. The one-hour photo finisher has become a boon to LALSR because it also allows inexpensive near-instant color review. All these film factors need to be considered for flight planning. If you have questions about film or film processing, consult Chapters 18 and 19. If manufacturing data are available and individual film tests have been made, it is easy to determine which film fits the situation.

F. Flying and Flight Lines

When mission planning is complete, load the camera and place it in the aircraft. Once the checklist is completed, it is time to fly. Most RPVs can be hand launched. The twenty feet per second at which they fly is not difficult to achieve by running and letting them fly into the air. These aircraft weigh between five and twenty pounds, and they get lighter as you run with them. Climbout is best in the area where the air is smoothest. Under most conditions, this means over homogeneous-colored, smooth surfaces. Avoid the leeward side of hills and cliffs.

Flight lines can be marked with surveyor's flagging tape on the ground or by individuals standing at each end of the flight line. At low altitude, these individuals are visible and easy to "line up on." With an RPV, one person stands on the approach end of the flight line, and the pilot occupies the position at the far end. The individual at the approach end signals to the pilot when the aircraft is overhead and when to shoot the camera. The last exposure is made when the aircraft passes over the pilot. As soon as one flight line is completed, the two people at the ends of the flight line move to their positions on the next flight line. About 20 exposures are made during most flights, and most of these flights last 10-12 minutes over the target area. When flight lines are complete, return the aircraft to the predetermined landing place and land it.

By using proper plotting techniques in situations where the terrain is constantly changing, daily or weekly overflights make it possible to create a microgeographic information system (GIS) in terms of location and stratigraphy.

At the completion of the flight, the object is to retrieve, process, plot, and interpret the film.

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PLOTTING

CHAPTER 14

A. Cataloging

As soon as the film is processed and printed, it is best to do the plotting. Start with the numbering (if you use a number system) and record the date, the flight time and the location on material that can be stored with the film and fed into your (computer, if needed) indexing system.

B. Area Plotting

If the photographs are of an area that has been or will be covered a number of times, they will need to be plotted on a sheet of paper, a map, or a small-scale photograph. Plotting on a standard USGS map can be difficult, because most of the LALSR single-frame photographs cover an area of about 1/8" by 3/16". Figures 14.1, 14.2, and 14.3 should illustrate the point. Figure 14.1 is a copy of a standard USDA photograph. Its original scale was 1: 40,000. The marked area is the area covered by Figure 14.3. Figure 14.2 is a copy of a topographic map of the same area and Figure 14.3 is also plotted on it. The usefulness of either of these plots is questionable.

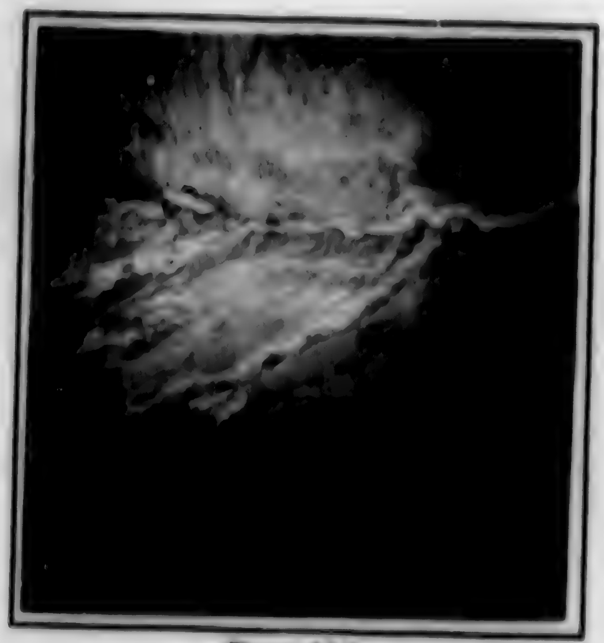

Figure 14.1
USDA Aerial Photograph of Beaver Dam Wash Area

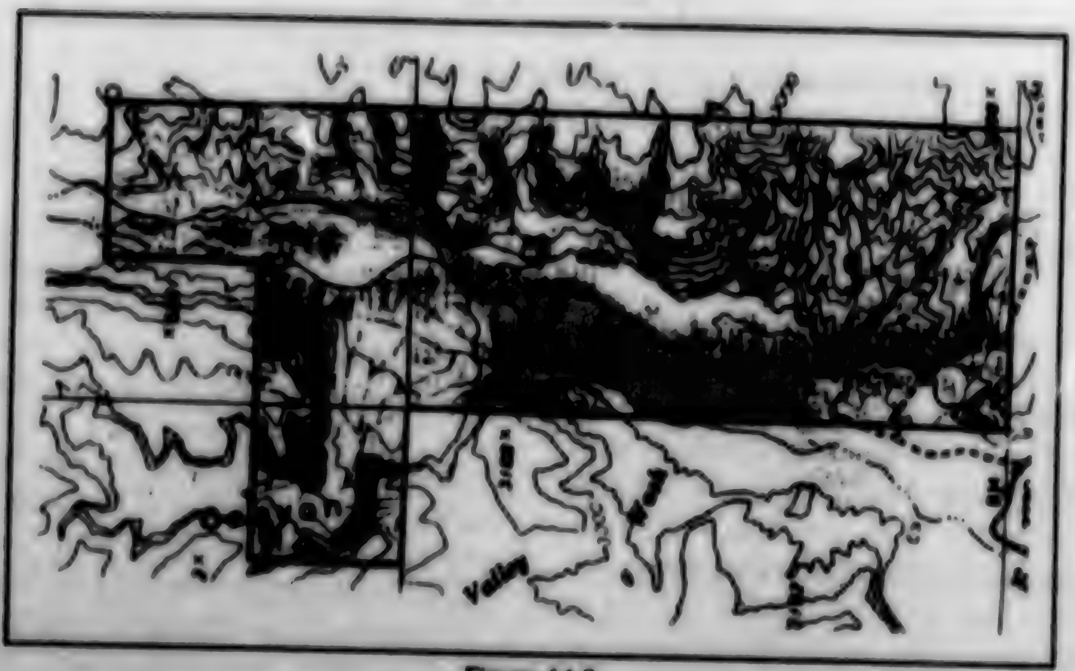

Figure 14.2
Topographic Map of Lytle Ranch Area

Figure 14.3
LALSR Photograph of Part of Lytle Ranch
(Note: This photograph covers an area of 600 x 900 feet. At the time of publication, it was the largest area covered by this type of photography. The aircraft was at 700 feet using a 28 mm lens.)

As additional photographs of Lytle Ranch are taken, this photograph will be more useful if it is plotted on a sheet of paper so that it can be compared to future photographs as they are plotted on the same piece of paper. Ideally, a large-scale map for plotting would be best.

These photographs can be plotted on large-scale maps using proportional dividers or a slide projector. Average scale in most instances is accurate within an inch or two. This is much better than smaller scale maps, where corrected imagery is accurate within six to eight feet. All images have better accuracy when image measurements can be radial, that is, when measurements are made outward, from as close to the center of the photograph as possible.

The use of proportional dividers is straightforward; simply set the difference in scale at the pivot and transfer dimensions from photographs to the map as needed. With slide projectors, a number of things can be accomplished. Place the projector on a tripod with an elevator crank and a pan head to give correction capability for yaw, pitch, and roll that were taking place when the photo was taken. A zoom lens on the projector can make altitude corrections. This approach makes it possible to start maps from the projected images, as well as add information to existing maps.

C. Uncontrolled Mosaics

Uncontrolled mosaics are useful for image interpretation, plotting, and starting a data base. Their accuracy is usable but questionable. They are usually quite easy to put together if only one flight line is used. My approach is to cut ten percent of the image from both of the overlapping ends (this still leaves forty percent overlap on stereo pairs), and to peel the resin coating from the back of each print with a dowel (Figure 14.4). Mount one print on a sheet of dry mount board, then proceed in either direction along the flight line, one print at a time, mounting each so that it fits in line and all the details between the two prints match. A little hand tearing along the edge of the print interface is usually necessary. The results can look at least as good as Figure 14.5.

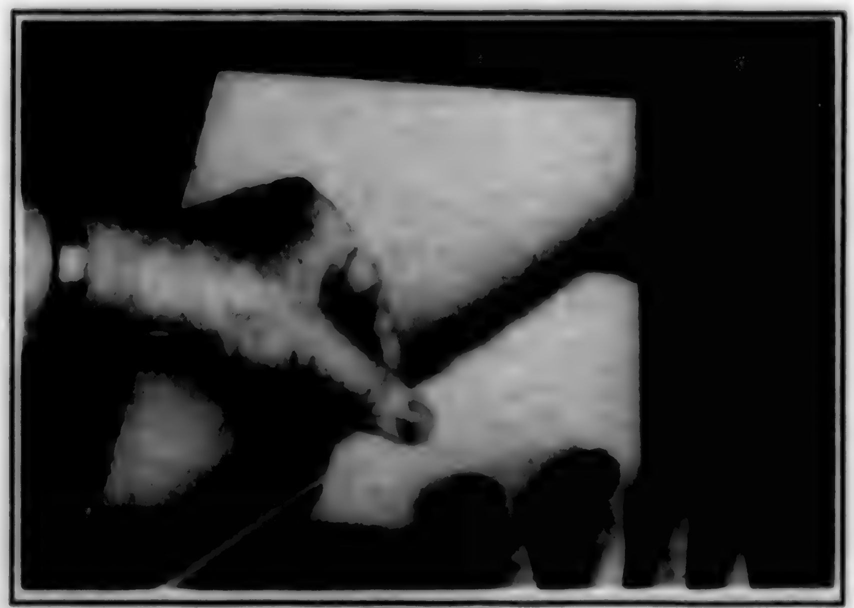

Figure 14.4
Peeling the RC Layer From the Back of a Print

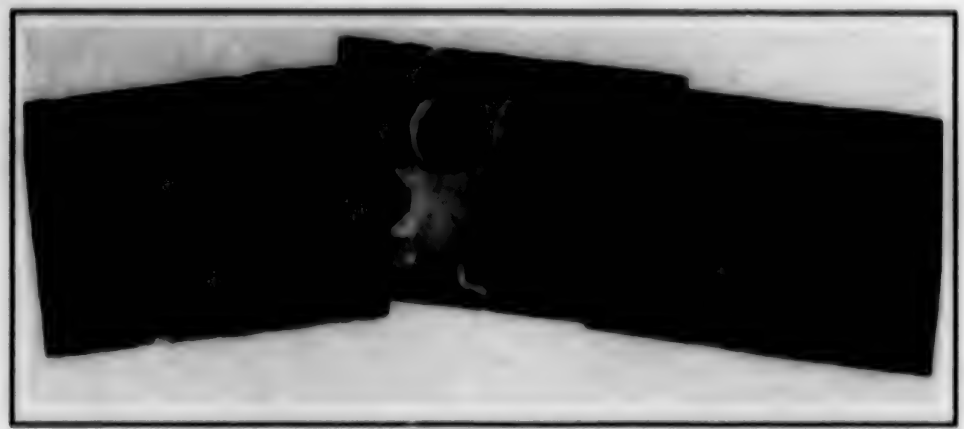

Figure 14.5
An Uncontrolled Mosaic

D. Pixel Detailing

One of the most difficult items to plot is a single photograph on satellite imagery because the coverage at optimum altitude is 1 x 1-1/2 satellite pixels in area. This type of coverage is when there is a need to see detail of a pixel area because it has changed on the satellite image. The coverage of figure 14.3 is an extreme example. It is 18.3 by 27.5 satellite pixels.

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ANALYSIS AND IMAGE INTERPRETATION

CHAPTER 15

As new, highly detailed imaging systems develop, new keys to interpretation must also be developed, especially when distance and perspective change dramatically. LALSR imagery is close to the ground, so it eliminates many traditional visual cues that exist in most aerial images. The perspective problem is like looking at rust on wire bristles without seeing the whole wire brush. With LALSR, individual species of plants are recorded rather than general types of vegetation.

Because of the increased surface detail available with LALSR, a publication that covers image interpretation (II) keys would be too voluminous. For this reason, a user approach to the development of II keys for LALSR is more useful and economical. Users, knowing their needs and environments, can best select and create appropriate keys. These keys are based on the visual cues, perspective, and scales peculiar to LALSR. Personal created keys of this type can be enhanced by system operators during flights because of their proximity to the target area. The potential of this system for on-site processing can also assist the user in key definition. Example projects are outlined in this chapter.

A. Background

LALSR as it initially developed at Brigham Young University was a tool for the archaeologist. However, as researchers in allied fields became acquainted with this imagery, it became obvious that it had applications in their work. As they started using LALSR imagery, a new set of interpretation rules for their particular disciplines evolved. Further, where multiple disciplines were involved, multiple interpretation rules evolved.

B. Basics of Image Interpretation

Before a set of interpretation rules is made for LALSR, it is best to examine some of the basics of image interpretation. Most images are interpreted in three phases. Phase one is a quick examination of the imagery for basic information. Phase two is an analysis of the imagery for fieldwork to determine additional courses of action. Phase three is detailed analysis with other available imagery and ground truth for reporting purposes.

Image interpretation keys are used to interpret and classify photographs. An II key is defined as "reference material designed to facilitate rapid and accurate identification of the significance of objects by the photo interpreter" (*Manual of Photographic Interpretation*, American Society of Photogrammetry, 1960). This reference material includes printed data, photographs, and personal knowledge. As new types of reconnaissance develop, most keys start as photographs and progress to a point at which they become either printed data or personal knowledge.

LALSR imagery is different from other imagery in six ways:

1. LALSR scales are usually between 1:100 and 1:1000.
2. LALSR is somewhat difficult to map reference because of its scale.
3. Surface objects look considerably different at low altitude. For example, power lines are visible from low altitude, and poles are no longer required for identification.
4. Because of the small area covered, most photographs are near planametric.
5. Interpretation is more specific. For example, pinion and juniper trees can be differentiated instead of being listed in one plant community.
6. Immediate, successive coverage is fast, easy, and economical.

Most LALSR image interpretation is classified into three categories:

1. Taxonomy (object identification and classification)
2. Position (relationship with other data in the photo)
3. Measurement (object size and shape).

The first step in interpretation is to decide which of the categories the needed information fits before flying. If contour plotting is needed, for example, it fits into both categories 2 and 3. Contour plotting means surveying enough control points to allow for computer plotting and knowing the requirements to meet the parameters for the plotter.

C. Interpretation

The first look at LALSR is, in most cases, somewhat dramatic. There is a tendency to want to return to the site to identify certain objects. This tends to make one more aware of the surroundings during the flight. Candy wrappers, aluminum cans, and disposable diapers suddenly take on new meaning. Items such as stream meander movement, reconstruction, and water turbidity become very noticeable. Bridge and fence construction techniques can be determined. Buried pipe systems over 100 years old are sometimes visible. At LALSR altitude, with most color films there is a difference in the color and shape of pinion and juniper trees. The same is true of cottonwood and Chinese elm. Also, the way some grasses spread as they grow and ripen is distinct. Once a discipline's essential material has been identified and recorded, and marked on the photographs, these records can become the image interpretation keys for repeated coverage. These keys also help when covering a similar area or an area where the material is different and creates a contrast. As coverage of different areas increases, information is obtained for additional keys, and previous keys become more refined. As keys develop for a particular discipline, the need for a content specialist becomes more obvious; and if a program begins without one, the search for one will start as key refinement begins. In most situations, work is performed with single objects and/or macro-environments; thus it pays to know and understand the environmental conditions in the surrounding area.

Mathematics, scale, and the measurements involved with LALSR imagery were discussed in Chapter 12. Elimination of blur was discussed in Chapter 11. Scale is a function of camera lens focal length and altitude, as discussed in Chapter 12. Scale = focal length/altitude, or if an enlarged print is used, then the enlarged scale is determined by multiplying the scale by the enlargement diameter. There are a number of ways to determine altitude after a flight. The simplest is to compare an object of known size on the ground to its measured size on the film:

Alt = Fl Os / Is.

In addition to the 1 x 1-1/2 meter colored cloth patches, other objects, such as painted lines on the road, or trash trolleys, have also been used. Once scale has been determined, it is merely a matter of multiplying any other object size on film by the scale.

D. Samples of Interpretation

With the exception of the building construction sequence, all other photographs in this chapter were in color. The interpretations were made on that basis. The color to black and white transition, along with photo-mechanical reproduction, have reduced information available in the photographs in this book. Content specialists were used, and most interpretation here is Phase One. Photographic processing was either of the one-hour or the twelve-hour type. Interpretation descriptions are with the photographs.

Figure 15.1
San Rafael Bridge

The bridge is a single-span suspension bridge 160 feet long. Details of construction are readily visible and are typical of those built by the Civilian Conservation Corps during the 1930s. A bypass road through the stream indicates a small load limit on the bridge. The bypass road indicates nearly as much use as the bridge. Signs and their shadows are visible; these probably indicate the load limit or bridge width. Construction is such that a height limit would not be applicable. Design is such that at extremely high water, cables could be undone and the bridge released, leaving the stabilizing structure unharmed and ready to be reused. Ground cover is sage, tamarisk, rabbit brush, grease brush, and June grass. The trees are cottonwood (broadleaf). Fence lines, as well as both the bridge cables and their shadows, are visible. Scale is altered because of printing processes. Area covered: 320 x 460 feet.

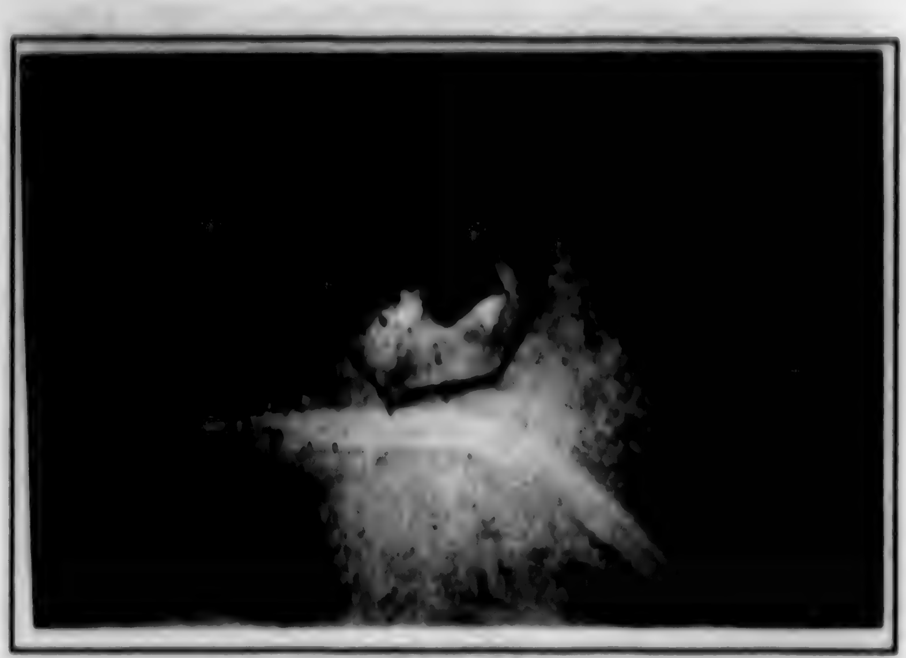


Figure 15.2
San Rafael Sink Hole

The sink hole is obvious. All shrubbery is within the fence, leaving only grass on the surface elsewhere. This is an indication of grazing problems. There is a high foot-traffic zone immediately around the fence. The fence uses double posts with spacers to hold the rails in position. Grass grows in circular patterns from a central root system. Note how the centers of each cluster appear to be dead and where these clusters have grown together. Cattle trails are visible in the upper part of the photograph, as is a buried pipeline. The evidence of the pipeline, which is estimated to have been buried for at least twenty years, is the tracks left by the track vehicles used in construction. The single track toward the top and the pair of tracks just below it are typical of present-day pipeline laying; if the same methods were used in the past, then it is evident that construction moved from right to left. Off-road vehicle tracks are prevalent in the area. Changes in their color are a function of their age. Area covered: 212 x 316 feet.

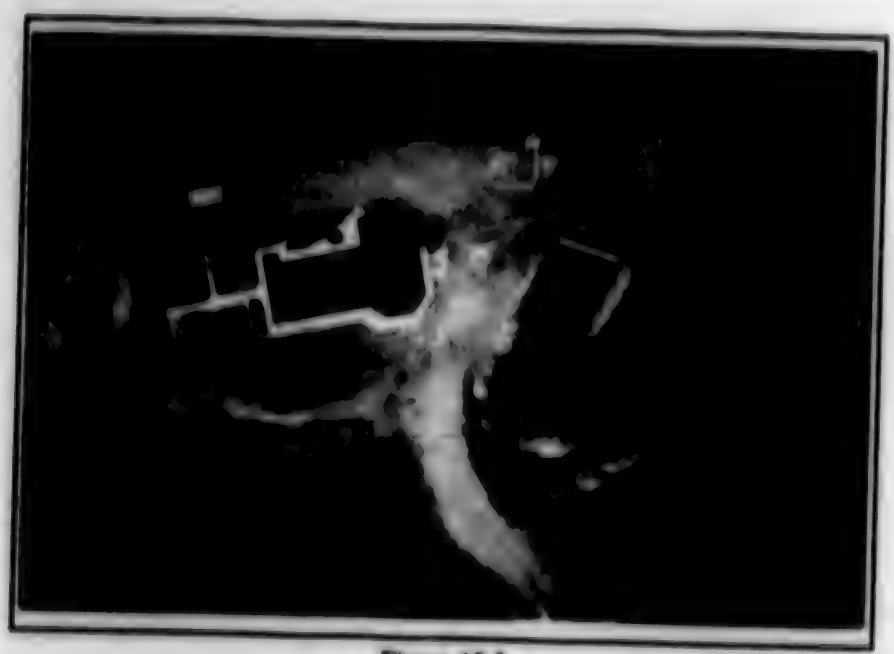


Figure 15.3
Strawberry Fish Hatchery

This hatchery was constructed where there was minimal damage to the environment. Even old stream meanders were avoided. Previous existing roads have been blocked. The dam's placement causes minimal stress to existing meanders along the stream. Area covered: 250 x 375 feet.

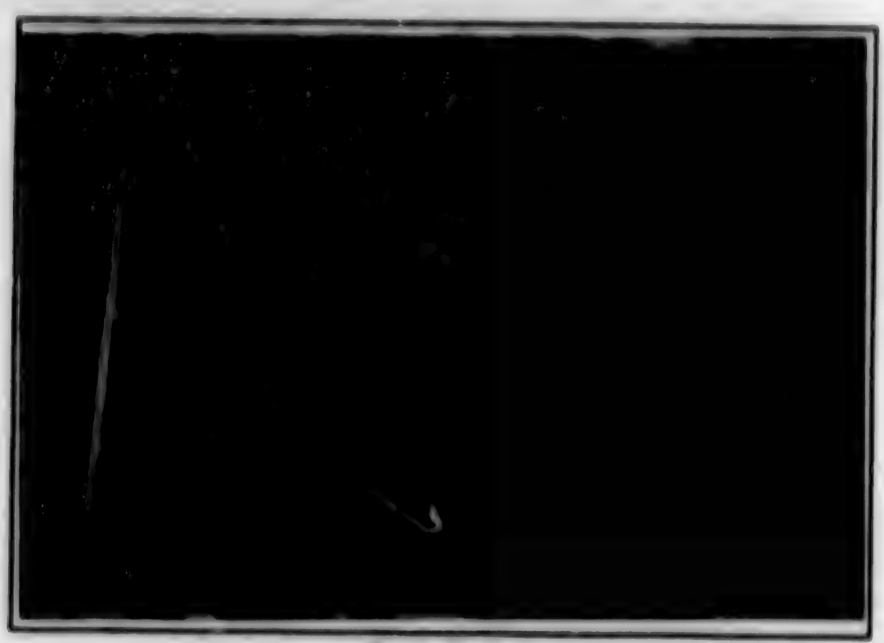
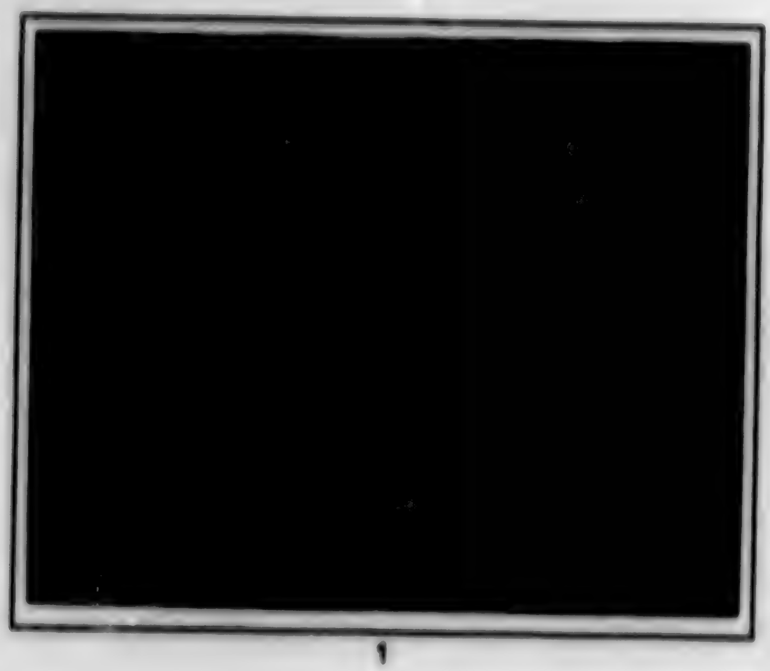


Figure 15.4.
Pulsating Sprinkler Tests at Utah State University

Growth and maturity are shown as a function of moisture distribution on an agricultural plot (original in color). Light green areas indicate excess moisture, deep green indicates normal moisture, and brown indicates too little moisture. The squares that look like black holes are moisture collecting gauges. The accompanying two photographs show the overall test plot from 500 feet and an eye level view from the ground.



1

2

3

Figure 15.5
Successive Coverage for Building Construction

The first flight photo shows the basic internal structure and floor plan of a single-story building. Debris associated with early phases of construction is visible, as is the storage place for the rafters when they arrived at the site (left center of the photo).

The second photo shows the roof top complete with lattice work for a ceramic type roof. Attached to the building are five flat structures, ready for concrete; there is also a structure a small distance away which has been freshly poured with concrete.

In the third photo this fresh pour has a spire mounted on it, and the five attached structures are pads for air conditioning equipment which is already mounted on three of them. The tile roof shows the color variations that exist between firing batches of tile--variations not visible from eye level. There has been very little work with the surrounding surface to indicate whether or not parking or landscaping will be adjacent to the building. The building dimensions are 86 x 186 feet.

E. Summary

In summary, there are no set rules for LALSR imagery interpretation. Determine which category or categories the images fit into, and act accordingly with targeting and ground truth. Then develop image interpretation keys with the help of the content specialist, both in the field and with the imagery. These keys can then be used for similar situations and for successive coverage. The low cost of obtaining this type of imagery encourages experimentation, and this usually results in discovering new keys and new approaches to interpretation. The only limitation of this experimentation is in your mind.

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TEACHING LALSR IN THE CLASSROOM

CHAPTER 16

The first class in low-altitude, large-scale reconnaissance was taught Winter semester 1990 at Brigham Young University (Figure 16.1). Each student completed a reconnaissance project, and five aircraft were built. There were nine students and two instructors. Post-class evaluations and student suggestions were included in the syllabus design. Many thanks to those students who contributed greatly to the success of this new class.

Figure 16.1
1990 LALSR Class

A. Text and Published Materials

This book was prepared as a text for this class. It attempts to bring together the disciplines of building, flying, mission planning, plotting, basic image interpretation,and basic photographic techniques. The success of LALSR depends on the user's ability to integrate these disciplines.

No attempt has been made to rewrite other source material. The following printed reference resources should be made available for student use.

Books:

Dewey, Don, *Flight Training Course, Vol. I*, R. C. Modeler Corp., Sierra Madre CA (1972).

Marks, Fred, and Winter, William, *Basics of Radio Control Modeling*, Kalmbach Publishing Co., Milwaukee, WI (1979).

Oke, T. R., *Boundary Layer Climates*, Methuen & Co., London (1978).

Strandberg, C. H., *Aerial Discovery Manual*, John N. Wiley & Sons, Inc., New York (1967).

Other Publications:

Caylor, J. A., Film, *Camera, and Mission Considerations to Reduce Image Motion Effects on Photos*, (Image Processing 89 Workshop, May 23-26, 1989).

Walker, J. W. , *A User Approach to Image Interpretation (II) Keys for Low Altitude Large-scale Reconnaissance(LALSR)*, Airborne Reconnaissance, XIII, 1989 SPIE Annual Conference, Vol. 1156.

Walker J. W., *The Image Motion Problem (IMP) as It Applies to Low altitude, Large-Scale Reconnaissance* (Technical Papers, 1990 ACSM-ASPRS Annual Conference, Vol. 5, pp. 119-127).

B. Class Outline

Each class is divided into two lecture periods of about one hour each, in most situations, each class period covers a different subject than the previous lecture. This lessens monotony and gives a clear reason for a break between lectures. There were fourteen class periods (28 lecture hours), and more than twice that many hours spent building or in imagery laboratories. A Macintosh disk, which contains the instructor's syllabus and class handouts, is available.

Figure 16.2
1991 LALSR Class

PART 4. PHOTOGRAPHIC CONSIDERATIONS

CAMERAS

CHAPTER 17

The cameras used with LALSR need to be lightweight and fully automatic in terms of shutter operation and film advance. With some types of reconnaissance operations, automatic exposure with a fixed high shutter speed is even more desirable. These cameras must have capabilities to be operated by the radio system that operates the aircraft, as described in Chapter 9. The operational connection between aircraft and camera must be electrical and not mechanical, to prevent air-frame and engine-vibration transfer to the camera.

There are six factors to consider when choosing a camera:

A. Weight

B. Environmental Effects

C. Service

D. Quality

E. Required Modification

F. Cost.

A. Weight

Weight is the most critical consideration, because increased weight means increased velocity, and this adversely affects the image motion (IMP). If weight becomes excessive, the aircraft will not fly. With the Butterfly aircraft, the camera weight cannot exceed fourteen ounces. Both camera and mount add eighteen ounces to the basic aircraft weight. This is a big load for a 0.15 engine at the 4,500 foot above sea-level launching altitude, where most of the initial test flights took place.

With the Senior Telemaster, the maximum allowable weight of the camera equipment is forty-one ounces. More weight increases the flying velocity significantly.

B. Environmental Effects

The effects of the LALSR operating environment on the camera are tremendous: flying introduces constant vibration (although this is minimal if the mount was properly designed), dirt (from landing) and engine oil getting on it, or it is jarred during the landing. One water landing or hard ground scrape can play havoc with the camera if it is not durable.

C. Service

Service is very important. With the treatment these cameras receive, damage is inevitable. When there is a water landing, it is nice to know that repair service is available. Repair and service costs can become a critical problem. Know your camera repair person and the manufacturer who backs him or her.

D. Quality

It may seem amazing that quality is listed fourth, but if the camera weighs too much, or it will not tolerate the environment, and if service is not available, then there is no quality to worry about. High-quality optics are paramount but they must not increase the weight of the aircraft. The lens sharpness is a function of manufacturing processes, and not lens speed. High-speed lenses do nothing but increase weight, because in LALSR there is little low, light-level photography. There are three basic types of shutters for 35mm cameras. The one with the fastest shutter speed is best. Ask your local camera serviceman (not salesman) which shutter is the fastest and most accurate for your climate. This can help you decide on appropriate camera equipment. An ideal camera weighs under ten ounces, has a shutter speed of 1/1000 of a second, has a high-quality 35mm or 50mm lens with a maximum opening of about f-3.5, and an automatic film winder that can be electrically driven. It does not have a pentaprism or a high-speed lens to add weight to the system.

E. Required Modification

Some cameras will require modifications to the triggering mechanism for use with LALSR. This can be expensive or even impossible. If your camera cannot be modified easily for an electronic closure of the shutter and for the advance operation, there will be trouble with your whole program. Let a qualified camera craftsman make the necessary modifications. Electronics are more complex now than they were a few years ago. For use with the

Butterfly aircraft, several small cameras, such as Ricoh's FF-90-Super and FF-7 have built-in electrical cable releases. A camera with this type of hookup requires no modification and is perhaps the best way to go. The new Ricoh AF, which also has this type of hook-up, weighs only ten ounces. This is a real advantage.

F. Cost

Cost of camera equipment is always a consideration, but most cameras used with LALSR are not too expensive. If no modifications are required, the cost is even better.

G. Camera Test Program

Ricoh Corporation and E.B. Wilson Public Relations (and now Jean Dynow Associates) furnished the high-quality, lightweight camera equipment for the initial LALSR system testing and development. The cameras used during these developmental stages were Ricoh's FF series cameras (FF-90 and FF-90-Super) for the Butterfly aircraft and Ricoh's KR-30 camera for the Senior Telemaster. The initial test camera was a Ricoh FF-90, modified to operate electronically with the radio equipment. This camera was the lightest automatic model available at that time. The Butterfly model aircraft still flies within the desired velocity envelope for LALSR work with the FF-90 mounted under it. Ricoh has since furnished an updated version, the FF-90 Super-D, which requires no modification and appears to have better optics and operating characteristics. We still use these three cameras with our operational programs.

A Ricoh KR-30SP camera with auto-wind was mounted in the Senior Telemaster. The lightest single lens reflex camera available at that time, it has excellent resolution capabilities (Figure 4.1). It has been on board for about 100 flights, has survived three major crashes, and is still being used. The Telemaster has also flown satisfactorily with an Olympus OM-1, a Konica 35mm camera, and a television camera. Other cameras within the weight limits can and will be tested as requests are made or as the need arises.

Figure 17.1
Ricoh FF-90 Modified

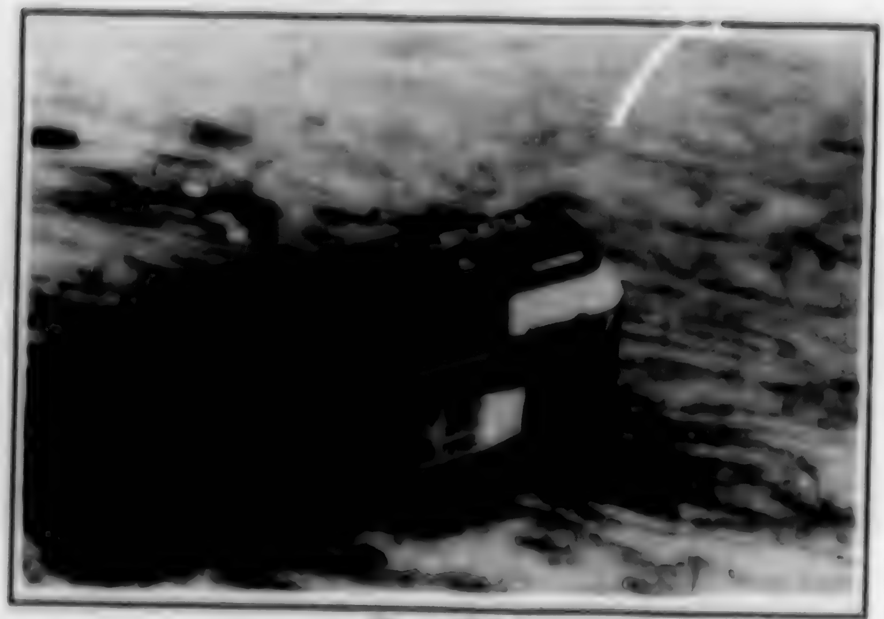

Figure 17.2
Ricoh FF-90 Super

Figure 17.3
Ricoh KR-30

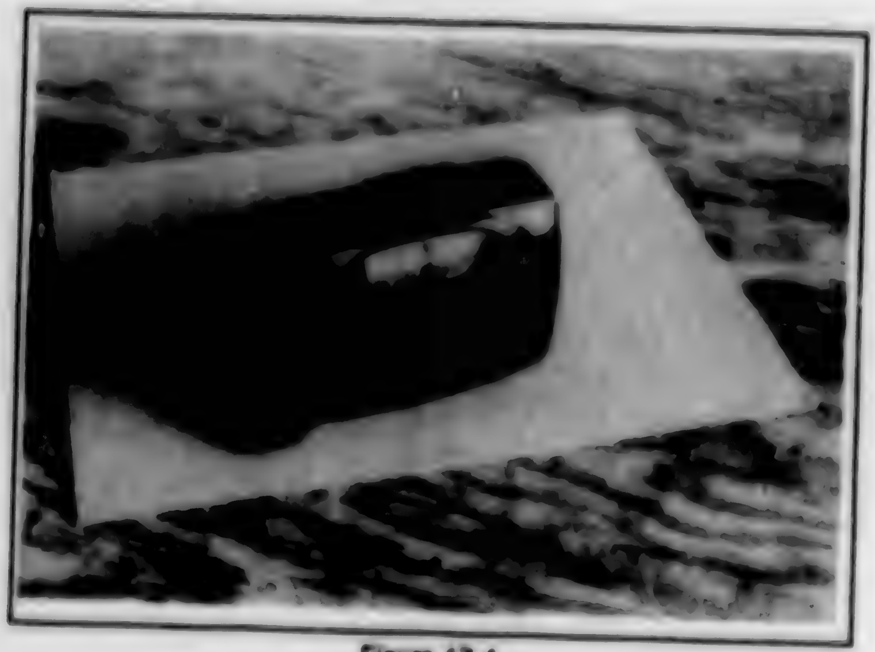

Figure 17.4
Ricoh FF-7

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FILM

CHAPTER 18

Film in 35mm format is available in more variety than any other format. For instance, a recent survey of a local film supply house revealed sixteen different 35mm color reversal film types in stock. This is only one category of film. Films fit into four general categories:

A. Black and white

B. Color negative

C. Color transparency (slides)

D. Special emulsions.

No single type or category of film will work for all situations.

A. Black and White Films

Black and white films are used when color brightness delineation and contrast are critical. They appear visually sharper than some types of color film. They can be filtered with monochromatic filters to produce color differentiation, that is, to show minute changes in a single color in exaggerated gray scale. Development time of black and white negative film can also be used to control contrast and thus control the shadow detail. For instance, T-Max 100 film is used for many LALSR projects and is consistently exposed at an ISO of 200 and developed longer to increase the contrast of the shadow detail. The color sensitivity of black and white film varies, and this can be advantageous. Technical pan film is more red sensitive than T-Max 100 film, which is more red sensitive than Plus-X film. Technical pan film can do an excellent job of recording old asphalt roads built in red soils in the spring when the green foliage is well established. Black and white films are also often used when extreme size and other enlargements are necessary.

B. Color Negative Films

Both black and white and color negative films are used for large prints; the environment and lab proximity can determine which is the faster to obtain. Color negative film is often used for quick results when one-hour photo finishing plants are close. It is in itself one of the best reasons to use color negative films. Color is one of the best tools for image interpretation. Color is its own salesman, although sometimes it is misused. Object differentiation is easier in most situations when photos are in color. On-site examination and ground truth work is easier with color prints for many types of measurement work. There is also some indication that the water penetration capabilities of the two Kodacolor Gold films (100 and 200) are different from each other and from other color films. Kodacolor Gold 200 film seems to see deeper into water with soluble iron and sodium in it than the 100 film. One hundred film seems to see deeper into water with soluble calcium than the 200 film. This phenomenon has not had sufficient data gathered yet to permit positive statements about it, but there is enough information to indicate that a full study should be made.

C. Color Transparency Films

Color transparency films are best for stereo-plotting, projection, photomechanical reproduction, and multi-image progress reports. The amount of time required for film processing may be either advantageous or disadvantageous. E-6 process emulsions can be processed locally in most areas within three or four hours; they have even been processed at remote locations. Most Ektachrome and Fujichrome films are E-6 process. Kodachrome films require a different process, which takes longer because of the distance to the labs. However, since the most common use for Kodachrome 200 film is stereo plotting, this long processing period is not usually a hindrance. Kodak and Fuji now manufacture some higher saturation color films, which tend to amplify and exaggerate colors; these features are helpful in photographing places with little color contrast.

D. Special Emulsion Films

Special emulsions are used to obtain special results. The best example of a special emulsion is color infrared film, which records photosynthesis in the form of red colored exaggerations of the most active plants. When you run into a special recording problem, the best approach is to contact your local film technical service representative (TSR). Your local camera dealer should have his or her name and phone number.

E. Film Speed

Film speed (ISO) requirements are determined by available light. To keep IMP at a minimum, the fastest possible shutter speed is needed. Therefore, with an automatic camera, the film speed that will set the shutter speed at its maximum for the existing lighting conditions should be used. With the automatic cameras used on the Butterfly, a film with an ISO of at least 200 is required for the camera operate at maximum shutter speed on a normal sunny day. With an adjustable shutter camera, it is possible to use a ISO 25 film and a shutter speed of 1 / 1000 second. It is desirable to have an f-stop, shutter speed, and EV plot for the camera used for your flights. With this information, you will at least be able to calculate what film speed to use. It is also desirable to use the slowest film speed possible, because the grain size is smaller on slow films. The film must be fast enough for fast shutter speed, and yet slow enough to allow for big enlargements.

F. D-X Cassette Problems

Small automatic cameras use the D-X data blocks on the film cassette to determine exposure. When a change in film speed is needed (for contrast control) or a film cassette has no data block, then the data block output must be modified. This is accomplished by cutting out a correct information data block from a used cassette with sheet metal shears and taping it over the data block area on the unmarked or unused cassette with two-sided transparent tape. These used cassettes are usually available at most photofinishers for no cost. Data blocks with film speeds from ISO 25 to 400 have been cut out and used at various times (Figure 18.2). They are stored in the camera bag in a plastic film cassette holder.

Processing is always a consideration when determining film type. Rapid processing can be anything from a one-hour film processing plant to a portable darkroom on site. Remember, do not fly a "rush" mission with a film that will take two weeks to get processed.

Films	Type	Speed (ISO)
Plus-X Pan	Black and white	200
Technical Pan	Black and white	80
T-Max 100	Black and white	200
T-Max 400	Black and white	400
High speed Infrared	Black and white	50
Ektar 125	Color Negative	125
Ektar 25	Color Negative	25
Fujicolor 100	Color Negative	100
Fujicolor 200	Color Negative	200
Kodacolor Gold 100	Color Negative	100
Kodacolor Gold 200	Color Negative	200
Ektachrome 100	Color Positive	100
Ektachrome 200	Color Positive	200
Fujichrome 100	Color Positive	100
Fujichrome 200	Color Positive	200
Fujichrome Reala	Color Positive	100
Kodachrome 64	Color Positive	64
Kodachrome 200	Color Positive	200
Ektachrome Infrared	Color Positive	N/A

Figure 18.1
Films That Have Been Used with LALSR

FIGURE 18.2
D-X Data Blocks Cut from Old Cassettes

PROCESSING AND PRINTING

CHAPTER 19

Once the film is removed from the aircraft, it must be processed. When water is available, black and white film can be immediately processed. Where there is temperature controlled water, some types of color film may also be processed. One-hour photo finishing labs can produce color prints for rapid viewing. As the complexity of processing increases (special contrast control, large prints, Kodachrome processing, etc.), so does the time involved. In other situations, archaeological and paleontological projects have been photographed after the day's work was completed and then photos viewed to help in planning work for the following day. Portable darkrooms, and light tables are available, and if used, this type of program should be structured to suit the environment and other conditions.

A. Film Types and Processes

1. *Black and White films.* Most black and white films used will process in D-76 or a similar type developer. This type of developer allows for relatively fine grain, long gradation, and consistent contrast control when needed; it also has a relatively long shelf life. This type of developer will also process black and white infrared film. Remember, when processing, do it with permanence in mind. Prints from black and white film can be made on site, or at a photo

finishing lab, or at a custom lab. The size of prints should depend on the needs of the user.

2. *Color Films.* There are four types of processes used with color film; the process depends on the type of color film used. In the United States, most color reversal films (except Kodachrome) will process in E-6 chemistry. This process is now available in some of the one-hour finishing labs as well. However, most E-6 processing labs are set up on a four-hour schedule. Having this schedule can help you schedule your work each day. E-6 films can be processed by anyone wherever 100° F water is available. It is not difficult, and obtaining the processing equipment costs under one hundred dollars.

Kodachrome film processing requires specialized processing equipment. This means mailing the film to processing centers. Depending on the location of the reconnaissance flight, can take between one and ten days. Keep this in mind as you plan your flying.

Color negative films process in C-41 chemistry. This type of processing is the easiest to obtain. Because in most situations, color negatives are difficult to interpret, prints are more desirable, and it is better if processing includes a set of prints. A small set of prints also helps in planning when two or three larger prints are going to be needed.

Color infrared film is processed in E-4 chemistry, which is somewhat difficult to obtain. It is better to have this film processed by a special finishing plant. Addresses of these processing plants are listed in photographic magazines and aerial photographic journals.

B. One-Hour Photo Finishing Plants

One-hour photo finishing plants are convenient; often, because they continue to exist solely on the basis of good service, they are willing to work with you and meet your special needs. For instance, a one-hour processing plant in Santa Fe, New Mexico, will immediately reprint the desired negatives needed to 8 x 12 inch prints. Adjusting your flying schedule to fit a finishing plant schedule helps you complete your work faster. The time is coming soon when there will be smaller portable processors in the back of pickup trucks and vans; these processors will be transported with your reconnaissance gear to a site and will process and print your film as soon as a flight is completed. These processors are now available, but the interfaces with the gear need to be worked out.

C. Large Print Availability

With proper processing, very large prints can be produced from 35mm film. Highly detailed thirty-diameter enlargements have been made from both Kodak Technical Pan film and its Agfa equivalent. This amounts to a 30 x 45 inch print. The images in this enlargement are sharp enough that you can discern the difference between animal (horse and cow) and human footprints at 400 feet altitude (Figure 1.7). Twenty-diameter prints have been made from Kodacolor Gold 200 and Kodachrome 200 films via Kodak's Poster Print program; the prints made from Kodachrome film via this program have an internegative made of the slide to maintain print quality equal to that of Kodacolor film.

There are two ways to obtain large prints: one is to have them custom finished; the other is to do it in your own darkroom. The cost and the environment determine which of these methods is best for the situation. Prints of all sizes can be made.

D. Specialized Images and Prints

Several types of image manipulation, such as posterization, can be accomplished by either using film or an electronic scanner (television camera). These image applications are highly specialized and can be accomplished by those with proper training. Seek help in this area if you need it.

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TV VIEWFINDER

CHAPTER 20

A viewfinder system consisting of a Sony HVM-302 camera with a small transmitter has been tested in the Telemaster aircraft. Our goal is for a resource specialist to indicate to the pilot when the aircraft is over the area that he wants to have photographed via a television monitor. An additional radio control channel to turn the television camera on and off saves battery drain by the television transmitter, which uses a different battery source than the rest of the aircraft. The addition of this unit will increase the total aircraft weight to sixteen pounds. Development is continuing on this system at a slow rate because of funding limitations. A number of problems remain yet to be solved

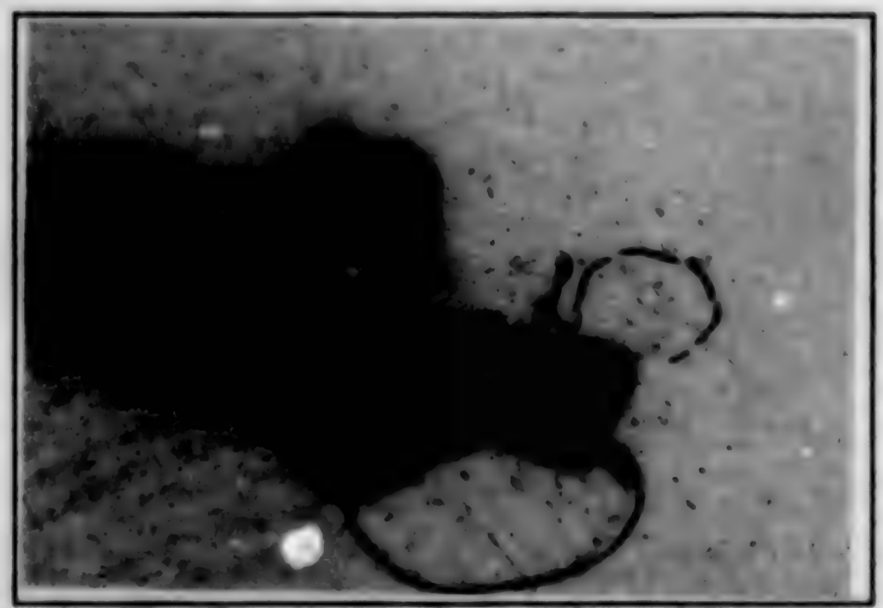

Figure 20.1
Sony HVM-302 in Sponge Mount

A. 60 Hz Problem

Many television cameras are turned off when the aircraft engine runs at 7200 rpm; this is a harmonic equivalent to 60 hz, the normal frequency for standard AC power in the United States.

B. Antenna Problems

The antenna used on the aircraft will work only directly overhead, because the power output permitted for unlicensed television is not strong enough to operate anywhere else. A lightweight antenna needs to be designed and tested for better performance. A receiver antenna tracking device also needs to be developed, and both of these items need to be cost efficient.

C. Transmitter

A better lightweight T.V. transmitter that will produce a more consistent output without draining the battery is also needed.

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APPENDICES

LALSR SAMPLES

APPENDIX A

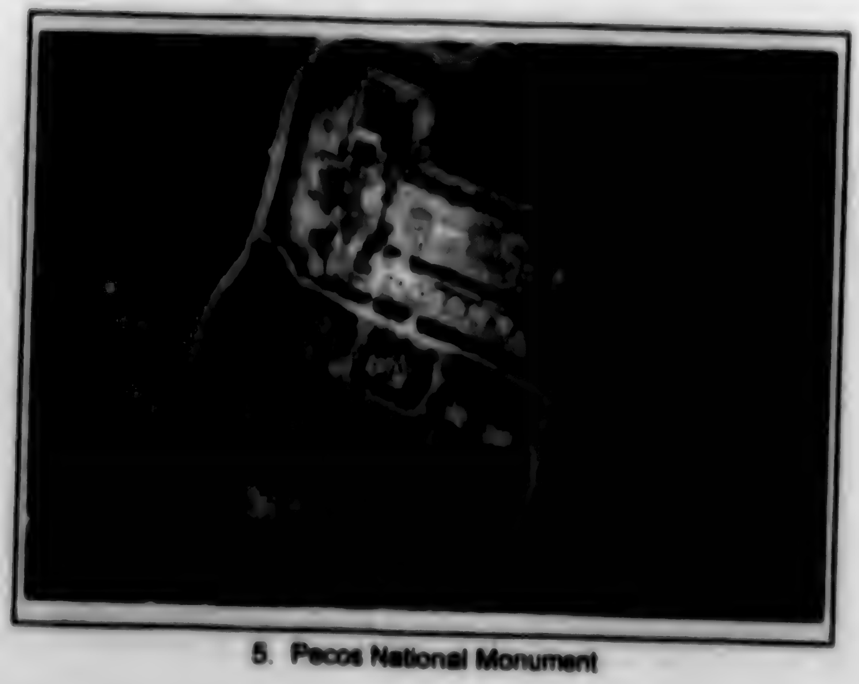
The following additional photographs are included for interpretation.

1. Wupatki Archaeological Site

2. Heiser Archaeological Site

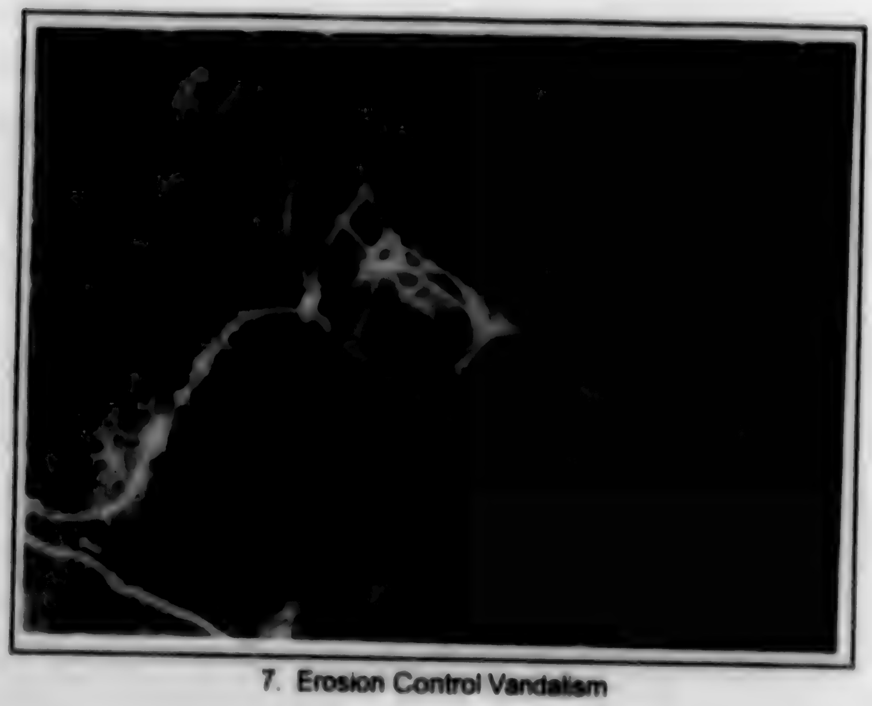
3. McIntyre Ranch

4. Pleasant Grove Water Tank



5. Pecos National Monument

6. Las Vegas LDS Temple



7. Erosion Control Vandalism

8. Promontory Point

FREQUENCY STATUS

APPENDIX B

As of January 1988, using old colored flag frequencies is no longer legal. Equipment on these frequencies will either have to be converted to a new numbered frequency or retired.

Eleven new numbered channels are added on the lower part of the 72 MHz aircraft band: 14 - 34. To ensure that this spectrum stays clean, The Academy of Model Aeronautics (AMA) Frequency Committee has dictated that these new channels be reserved for narrow band transmitters *ONLY*. This means that transmitters must broadcast within certain specifications and not "splatter." The frequency must not exceed ±1500 Hz from the operating frequency, and the sidebands must be at least 55 decibels down at 20 KHz out. This new specification involves transmitters only, not receivers.

The Frequency Committee of the AMA is planning to petition the FCC to change the law to solidify specifications, but that will take time. Until then, all manufacturers and importers under the body of RCMA (R/C Manufacturers Association) have agreed to abide voluntarily by the mandate, and narrow band transmitters will be identified by an appropriate sticker. Channel 12 falls into this "lower band" category; transmitters on this channel 12 are required to be narrow banded.

The situation in 1991 is still the same. We will implement all 80 of the channels (actually a few less), including the odd-numbered ones. This environment will require both narrow band transmitters and receivers.

To eliminate confusion when adding the new lower band channels, a new frequency flag system has been implemented. Your local hobby dealer is the best source of information of this change.

Summary of Usable Aircraft Frequencies

27 MHz band: No anticipated changes.
50 MHz band (Ham license required): Channels 00, 01, 02, 03, 04, 05, 06, 07, and 08 after 1991.
53 MHz band (Ham license required): 53.1, .2, .3, .4, .5, .6, .7, and .8.
Lower 72 MHz band (aircraft only): Channels 12 - 34 (narrow band only).
Upper 72 MHz band (aircraft only): Even channels only (38-56), with use of odd channels at local discretion.

STARTER CART

APPENDIX C

Many have asked about a starter cart and its use. In whatever form (cardboard box or very fancy), it should contain the at least the following if you are going to use a starter:

12 volt battery
1.5 volt battery
1 gallon fuel (5%)
2 screwdrivers (regular and Phillips)
1 starter
1 prop and glo-plug wrench
fuel pump or fuel bulb

Room for spar rod, rubber bands, and spare parts.

GLOSSARY

APPENDIX D

Aerodynamic drag. Drag caused by motion of the aircraft through the air.

Airfoil. The cross section, front to rear of a wing, the shape of which determines lift.

Anti-halation. Backing on film to lower reflection within the film and make images sharper.

Aspect ratio. The ratio of the wingspan to its width.

Base stock. The material upon which film is coated, usually a clear plastic such as acetate.

Butterfly. A model airplane kit available at most hobby stores and used for LALSR.

Cellotex. A soft flat insulating board material upon which model aircraft can be built (strawboard).

Center of gravity and balance jigs. A device to check the balance of an aircraft or part.

Clevis. A small device used to connect control rods to control surfaces.

Coax cable. An electrical cable shielded from electrical interference.

Colored flag frequencies. An old outdated method of marking the frequencies used by radio control pilots.

Contour plotting. Contours are lines of equal elevation on a drawing or map. Plotting of these lines using pairs of vertical photographs is contour plotting.

Critical dampening length. The directional length used to stop harmonic wave action in an object.

Dihedral angle. The angle above horizontal of the wing of an aircraft.

Dihedral blocks. Blocks of wood which are used to hold wings at the proper dihedral angle while gluing an aircraft wing.

Dikes. A pair of pliers with an edge for cutting wire.

Dremel Tool. A small rotary electric hand tool used to cut and abrade material in order to shape and polish that material.

Dust devils. Miniature tornado-like wind. A small-scale heat macro-low common in the southwest and west deserts.

Engines and their sizes. Model aircraft engines are available at most hobby stores. They are fueled by alcohol and castor oil. Their size is measured in terms of their piston displacement. This measurement is in cubic inches. A small engine is 0.15 and a large model engine 0.61.

Exposure value. A photographic relationship between light level and film speed expressed in numbers and used to adjust automatic electronic cameras.

Film emulsions. The light sensitive coating on film. It is described in terms of light sensitivity (speed), and type (black and white, color negative, color transparency, etc.).

Fuselage jig. A device to hold an aircraft fuselage in alignment during its construction.

Glo-plug. An electrically heated plug used for starting a model aircraft engine.

Ground truth data. Reconnaissance data gathered from the ground and the area surrounding to assist in obtaining optimum information of a photographed area.

Ground work. Work accomplished prior to beginning a project.

Haze. Light phenomena caused by the sunlight reflecting off from and around particles in the atmosphere. Haze usually degrades an image.

Image math. Mathematics involved with obtaining imagery and data from the imagery.

Image-motion problem. Blur of an image due to motion of the aircraft during a photographic exposure.

Interface angle. The angle at which two surfaces meet.

Intervalometer. A device to automatically measure the time between exposures with a camera.

Large scale imagery. See the first paragraph, Chapter 2, page 8.

Low-altitude, large-scale reconnaissance aircraft. Remote controlled aircraft used to obtain photographic imagery.

Monocote (brand name). A mylar shrink coating used to cover model aircraft.

Operation envelopes. Limitations within which an aircraft operates.

Penta-prism. The optical device used in a single-lens reflex camera as a viewfinder.

Pixel. The smallest defined piece of detail in an electronic image.

Planemetric. Flat measurement on a map or photograph.

Plotting. The marking, measuring, and annotating of a photograph or a map.

Power plant. See engines and their sizes in glossary above.

Power plant cyclic rate. The vibration rate of an internal combustion engine which also equals the revolutions per minute the propeller is turning.

Power-on stall. An aircraft stalling with full power on the engine.

Posterization. A photographic process using the principle of density slicing to emphasize a particular part of the view.

Preplanned damage. Damage to an aircraft which happens during landing because of limited landing conditions.

Radians. A mathematical measurement of angles.

Remote piloted vehicle. An aircraft which is operated remotely by a pilot from the ground using radio transmitter

Roll rate. The rate at which an aircraft rotates around its longitudinal axis.

Scale. The ratio between image size and object size on a photograph, map, or drawing.

Servo. Servomotor. A radio controlled device used to move the control surface s in an aircraft.

Slant tank. A type of model aircraft fuel tank used for easy installation.

Stereo pairs. Two photographs exposed so they overlap by at least 60%. These photographs can be used to see in stereo (three dimensions) and to contour plot.

Stringers. The length wise reinforcements which traverse the long length of an aircraft structure.

T-grain coating. A type of film emulsion coating which produces a fine grain film.

Telemaster. A model airplane kit available a hobby store and used for LALSR.

Temperature inversion. A climatic condition where temperature rises as elevation increases. This condition traps dirt and particles at lower elevations and increases the haze.

Ultralight aircraft. Piloted aircraft which weigh under 256 pounds empty and carry less than five gallons of fuel

Uncontrolled mosaic. A series of photographs put together so their edges match, but they are not necessarily dimensionally correct.

Unit balance factor. See page 80, line 16, and ubf in the acronyms.

Vibration control area. The camera compartment is the vibration control area. The space within the compartment is the soft area and the box which surrounds this space is rigid to transfer vibrations around and past the soft area.

Visual crossover. A condition of realizing that the aircraft controls reverse to the visual when an aircraft travels towards a pilot as opposed to away from the pilot.

Zap. A brand name for cyanoacrylate adhesive.

ACRONYMS

APPENDIX E

ac	alternating current
Alt	altitude
AMA	Academy of Model Aeronautics
ASA	film speed, now replaced by ISO
ASL	above sea level
B	image blur
B&W	black and white film
CG	center of gravity, or balance point
EV	exposure value
FAA	Federal Aviation Agency
Fcl	35mm field of coverage, long dimension
Fcw	35mm field of coverage, width, or short dimension
Fl	focal length
ft	feet
FRU	feature recognition unit--the smallest recognizable feature recorded on film
GIS	geographic information system
HDF	H. Del Foster, a stereo computer plotter manufacturer
Hz	frequency (cycles per second)
IMP	image motion problem
in	inches
Is	image size
ISO	present film speed index used on most films
kg	kilograms
LALSR	low altitude large-scale reconnaissance
L / mm	lines per millimeter, a resolution measurement
mm	millimeters
mph	miles per hour
neg	negative processed film
n/a	not applicable
n.o.	normally open connection
Ol	overlap time between the exposure of two photographs
Os	object size

oz	ounces
pos	positive processed film (transparency)
PVC Pipe	white plastic pipe
RC	radio control
RCM	*Radio Control Modeler* magazine
RPM	revolutions per minute
RPV	remote piloted vehicle
Rs	system resolution
Sc	scale expressed as a fraction
sec	seconds
SLR	single lens reflex camera
SPDT	single pole, double throw
Sr	the reciprocal of the scale expressed as a number (1/Sc)
SRPV	slow-flying remote piloted vehicle
Ss	shutter speed in seconds
TSR	technical service representative (usually product related)
ubf	unit balance factor. This number corrects for dimensions that are in different systems, i.e., focal length in millimeters with altitude in feet
v	velocity measured in distance per unit of time
VOX	voice operated switch

REFERENCES CITED AND SELECTED BIBLIOGRAPHY

APPENDIX F

Aikens, C. M., W. G. Loy, M. D. Southard, and R. C. Hanes, *Remote Sensing A Handbook for Archeologists and Cultural Resource Managers Basic Manual Supplement: Oregon*, Supplement No. 4, National Park Service, Washington, DC (1980).

Allen, R., J. Judge, J. W. Walker, and R. Watson, "Interfacing of Magnetometer Maps and Low Altitude Large-scale Reconnaissance (LALSR) Imagery." (Technical Papers, 1992 ASCM-ASPRS 58th Annual Convention, Vol. 1, pp 529-538, 1992).

American Society of Photogrammetry, *Manual of Photographic Interpretation*, American Society of Photogrammetry, Washington, DC (1960).

American Society of Photogrammetry, *Manual of Photogrammetry*, 3rd. ed., American Society of Photogrammetry, Washington, DC (1966).

American Society of Photogrammetry, *Manual of Color Aerial Photography*, American Society of Photogrammetry, Washington, DC (1968).

American Society of Photogrammetry, *Manual of Remote Sensing*, 2 Vol., American Society of Photogrammetry, Washington, DC (1975).

Anderson, B. A., *The Wupatki Archeological Inventory Survey Project: Final Report*, Southwest Regional Office, Division of Anthropology, Southwest cultural Resources Center, Professional Paper No. 35.

Andersen, B., A. K. Ireland, and J. W. Walker, "Low Altitude Large-scale Reconnaissance (LALSR) at Wupatki National Monument, a Study in Continuing Coverage at Nominal Cost." (Technical Papers, 1992 ASCM-ASPRS 58th Annual Convention, Vol. 1, pp 149-156, 1992).

Avery, T. E., *Interpretation of Aerial Photographs*, 3rd ed., Burgess Publishing Company, Minneapolis, Minnesota (1977).

Avery, T. E., and G. L. Berlin, *Fundamentals of Remote Sensing and Airphoto Interpretation*, Macmillan Publishing Company, New York (1992).

Avery, T. E., and T. R. Lyons, *Remote Sensing: Aerial and Terrestrial Photography for Archeologists*, Supplement No. 7, National Park Service, Washington, DC (1981).

Babington-Smith, C., *Air Spy, The Story of Photo Intelligence in WW2*, Ballentine Books, New York (1957).

Baker, C., and G. J. Gumerman, *Remote Sensing: Archeological Applications of Remote Sensing in the North Central Lowlands*, Supplement No. 6, National Park Service, Washington, DC (1981).

Camilli, E. L., and L. S. Cordell, *Remote Sensing: Applications to Cultural Resources in Southwestern North America*, Supplement No. 8, National Park Service, Washington, DC (1983).

Caylor, J. A., Film, "Camera And Mission Considerations To Reduce Image Motion Effects on Photos," (Image Processing 89 and Twelfth Color Aerial Photography and Video Workshop, May 23-26, 1989.).

Colwell, R. N., *Manual of Remote Sensing*, ASPRS (1983).

Crawford, O. G. S., *Air Survey and Archeology*, 2nd ed., Professional Papers, new series no. 7, Ordnance Survey, London (1928).

Crawford, O. G. S., *Air Photography for Archaeologists*, Professional Papers, new series no. 12, Ordnance Survey, London (1929).

Dewey, D., *Flight Training Course*, vol. 1 R/C Modeler Magazine, Sierra Madre, Ca. (1972).

Deuel, L., *Flights Into Yesterday*, St. Martin's Press, New York (1960).

Drager, D. L., and T. R. Lyons, *Remote Sensing Photogrammetry in Archeology: The Chaco Mapping Project*, Supplement No. 10, National Park Service, Washington, DC (1985).

Eastman Kodak Co., *Applied Infrared Photography, Technical Publication M-28*, Eastman Kodak Co., Rochester, New York (1967).

Eastman Kodak Co., *Kodak Data for Aerial Photography*, Eastman Kodak Co., Rochester, New York, Publication, M-29 (1982).

Eastman Kodak Co., *1989 Technical Information*, Kodak Professional Products, Eastman Kodak Co., Rochester, New York, Code X2-25, Cat. No. 9037771 (1989).

Eastman Kodak Co., *Kodak Color Films and Papers for Professionals*, Eastman Kodak Co.,Code E-77, Rochester, New York (1986).

Eastman Kodak Co., *Kodak Infrared Film, Technical Publication N-17*, Eastman Kodak Co., Rochester, New York (1968).

Eastman Kodak Co., *Kodak Professional Black & White Films*, Kodak Professional Products, Eastman Kodak Co., Rochester, New York, Code F-5 (1989).

Ebert, J. I., Remote Sensing Applications in Archeology, *Advances in Archaeological Method and Theory*, Vol. 7, edited by M. B. Schiffer, pp. 293-362, Academic Press, Orlando, Florida (1984).

Fouch'e, P. S., and N. W. Booysen, "Remotely Piloted Aircraft For Low Altitude Aerial Surveillance In Agriculture," Image Processing '89 and Twelfth Color Photography and Videography Workshop (May 23-26, 1989).

Hinckley, T. K., "Teaching Low-Altitude/Large-Reconnaissance," (Technical Papers, 1992 ASCM-ASPRS 58th Annual Convention, Vol. 1, pp. 133-138, 1992).

Lee, W. T., *The Face of the Earth As Seen from the Air*, American Geographic Society, New York (1922).

Lyons, T. R. (ed.), *Remote Sensing Multispectral Analyses of Cultural Resources: Chaco Canyon and Bandelier National Monument*, Supplement No. 5, National Park Service, Washington, DC (1981).

Lyons, T. R., and T. E. Avery, *Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers*, National Park Service, Washington, DC (1977).

Lyons, T. R., and T. E. Avery, *Remote Sensing: Practical Exercises on Remote Sensing in Archeology*, Supplement No. 1, National Park Service, Washington, DC (1978).

Lyons, T. R., and J. I. Ebert (eds.), *Remote Sensing and Non-Destructive Archeology*, National Park Service, Washington, DC (1978).

Lyons, T. R., R. K. Hitchcock and W. H. Wills, *Remote Sensing Aerial Anthropological Perspectives: A Bibliography of Remote Sensing in Cultural Resource Studies*, Supplement No. 3, National Park Service, Washington, DC (1980).

Lyons, T. R., and F. J. Mathien (eds.), *Cultural Resources Remote Sensing*, National Park Service, Washington, DC (1980).

Morain, S. A., and T. K. Budge, *Remote Sensing: Instrumentation for Nondestructive Exploration of Cultural Resources*, Supplement No. 2, National Park Service, Washington, DC (1978).

Principles and Practices for Precision Photographic Processing Laboratories, A. F. Manual 95-13, Vol. 1, Dept. of the Air Force, Wash. D C.

Randolph, R., *Radio Control Airplanes*, Air Age Inc., 251 Danbury Rd., Wilton Ct. (1990).

Randolph, R., *R/C Airplane Building Techniques*, Air Age Inc., 251 Danbury Rd., Wilton Ct. (1991).

Rees, W. G., *Physical Principles of Remote Sensing*, Topics in Remote Sensing 1, Cambridge University Press, Cambridge, England (1990).

Riley, D. N., *Air Photography and Archaeology*, University of Pennsylvania Press, Philadelphia (1987).

Scollar, I., A. Tabbagh, A. Hesse, and I. Herzog (eds.), *Archaeological Prospecting and Remote Sensing*, Topics in Remote Sensing 2, Cambridge University Press, Cambridge, England (1990).

Smith, H. T. U., *Aerial Photos And Their Applications*, Appleton-Century Co., Inc., New York (1940).

Spurr, S. H., *Photogrammetry and Photo Interpretation*, 2nd Ed., Ronald Press Co., New York (1960).

Strandberg, C. H., *Aerial Discovery Manual*, John N. Wiley & Sons, Inc., New York (1967).

Vogt, Evon Z., (ed.), *Aerial Photography in Anthropological Field Research*. Harvard University Press, Cambridge, Massachusetts (1974).

Walker, J. W., "Improvements in Low Altitude Aerial Photography Using Ultra-light Aircraft," (Abstract, Proceedings of Utah Academy 47:118-119, 1980).

Walker, J. W., "Ultra-light Reconnaissance, Another Tool" (Technical Papers, 51st Annual Meeting ASP, vol. I, pp 371-380, 1985).

Walker, J. W., "An Update on Low Altitude, Large-scale Reconnaissance," (Technical Papers, 1988 ASCM-ASPRS Annual Convention, Vol. 3, pp. 128-136).

Walker, J. W., "Low Altitude, Large-scale Reconnaissance: Detail>Expense," *Airborne Reconnaissances XII*, 1988 SPIE Annual Conference, Vol. 979, pp. 93.

Walker, J. W., "A User Approach To Image Interpretation (II) Keys for Low Altitude, Large-scale Reconnaissance (LALSR)," *Airborne Reconnaissance, XIII*, 1989 SPIE Annual Conference, Vol. 1156.

Walker, J. W., "The Image Motion Problem As It Applies To Low Altitude Large-scale Reconnaissance (LALSR)," (Technical Papers, 56th Annual Meeting ASPRS, vol. 5, pp.119-127, 1990).

Walker, J. W., "Camera Mount (Aircraft) Improvements for Low Altitude Large-scale Reconnaissance (LALSR)," (Technical Papers, 1992 ASCM-ASPRS 58th Annual Convention, Vol. 1, pp. 496-505, 1992).

Wilson, D. R., *Air Photo Interpretation for Archaeologists*, St. Martin's Press, New York (1982).

Wood, W. R., R. K. Nickel, and D. E. Griffin, *Remote Sensing: The American Great Plains*, Supplement No. 9, National Park Service, Washington, DC (1984).

IMAGE MATHEMATICS, CHAPTER 12 IN METRICS

APPENDIX G

This is a repeat of Chapter 12 for those who are fortunate enough to deal in a total metric system including altitude. As with chapter 12 it is divided into sections dealing with motion, scale, altitude, coverage, and overlap.

A. Motion

The distance an aircraft moves during a camera exposure is the image motion (IMP). This is measured in millimeters and is derived by multiplying the velocity of the aircraft by the amount of time the shutter is open. If the velocity is in kilometers per hours, the shutter speed in seconds, and the result is desired in millimeters, then the it must be multiplied by 1000 Kilometers per meter, 1000 millimeters per meter, divided by 60 minutes per hour and 60 seconds per minute:

$$1000 \times 1000/60 \times 60 = 278.$$

The answer, 278, is a unit balance factor (ubf). It corrects for dimensions that are in different units of measurement, i.e., focal length in millimeters and altitude in meters etc.. Therefore:

IMP = 278 v Ss
mm ubf Kph sec.

The blur (B) this motion (IMP) creates on the film in millimeters is 278 multiplied by the velocity in Kph, multiplied by the exposure time in seconds, multiplied by the focal length (Fl) of the camera lens in millimeters. This number is then divided by the altitude (Alt) in meters, or

B = .278 v Ss Fl / Alt
mm ubf Kph sec mm m

or

B = 100 IMP Fl / Alt
mm mm mm / m.

Further, when this blur is measurable on the film (when flying below optimum altitude), it is possible to calculate the velocity of the aircraft if the flight line is pretargeted with a one-meter square target. Use the short dimension of the target on the film to measure the altitude and the difference between the short and long dimensions on the target as the blur (B). Then:

$$v = 3.6\ B\ Alt\ /\ Ss\ Fl.$$

Figure 12.1 represents the relationship between focal length (Fl), altitude (Alt), object size (Os), and image size (Is). This clarifies the above equation if the object size is considered the IMP and the image size is considered as the blur.

With the camera focused at infinity, the diagram in Figure 12.1 indicates

$$\mathrm{Alt} / \mathrm{Os} = \mathrm{Fl} / \mathrm{Is}$$

or if dimensioned:

$\mathrm{Alt} / \mathrm{Os} = \mathrm{Fl} / \mathrm{Is}$
m / m mm / mm.

The focal length of a camera lens is fixed, the object size can be measured on the ground, and the image size can be measured on the film; therefore, the flight altitude can be calculated.

B. Scale

Scale is the ratio between a photograph and its full-sized counterpart, or the image-to-object ratio. For example, if a one-meter ground target measures one millimeter on film, then the scale is 1:1000. Therefore:

$$\mathrm{Sc} = \mathrm{Is} / \mathrm{Os}$$

or if dimensioned:
$\mathrm{Sc} = \mathrm{Is} / 1000\ \mathrm{Os}$
mm ubf m.

Optimum scale is achieved when the image motion (IMP) equals what the camera film system can record (resolution [Rs]):

$\mathrm{Sc} = \mathrm{Rs} / \mathrm{IMP}$
mm mm.

If the scale is the image-to-object ratio, then mathematically it is also the lens focal length (Fl) to altitude (Alt) ratio:

$$\mathrm{Sc} = \mathrm{Fl} / \mathrm{Rs}.$$

Some people prefer to use the scale reciprocal instead of the scale because it is a large number instead of a fraction. The scale reciprocal applies to Figure 12.2 which demonstrates how scale relates to image and object size. To use this equation, choose the unknown quantity and perform the mathematical function indicated by the position of the remaining two quantities. If the remaining two quantities are side by side, then multiply; if they are above and below, then divide the top by the bottom. Dimensions involved with this diagram will have to be unit balanced.

C. Altitude

Altitude is needed for two purposes with LALSR. To determine the altitude to fly an aircraft for a specified scale:

$$\mathrm{Alt} = \mathrm{Fl}\ \mathrm{Sr}$$

or if dimensioned:

$\mathrm{Alt} = \mathrm{Fl} \times \mathrm{Sr} / 1000$
m mm ubf.

To determine the altitude to fly an aircraft for specific coverage:

$$\mathrm{Alt} = \mathrm{Fl}\ \mathrm{Os} / \mathrm{Is}$$

where the object size is the coverage in feet and the image size is the film width in millimeters.

To determine altitude from imagery with the use of a one-meter target:

$\mathrm{Alt} = \mathrm{Fl} / \mathrm{Is}$
m mm mm.

With a Butterfly and Ricoh's FF-7 series cameras with 35mm focal length lenses:

Alt = 35 / Is

and with a single lens reflex camera (SLR) with a 50mm focal length lens:

Alt = 50 / Is.

If a different sized target is used:

Alt = Fl Os / Is.

The ubf depends on what the object size is measured in (meters,seconds, millimeters hours, etc.).

D. Coverage

Coverage is the area, length, or width that is covered on the ground by an aerial photograph. It is a function of the camera lens focal length and the altitude of the aircraft, so the preceding equations apply. The object size now becomes the ground coverage width (Fcw) or length (Fcl). The image size becomes 24 or 36 (film width or length in a 35mm camera). Therefore:

Fcw = 24 Alt / Fl and Fcl = 36 Alt / Fl
m ubf m mm m ubf m mm.

E. Overlap

Overlap is needed for two reasons with LALSR: to produce stereo images for stereo viewing and plotting, and to produce a continuous long-strip photograph. The overlap for obtaining stereo photographs must exceed 56%; however, 60% is the amount desired by most cartographers. With 35mm imagery and the direction the format is turned in the aircraft, the overlap is in the long direction of the film (Fcl). For 60% overlap, 0.6 Fcl of one photo must overlap 0.6 Fcl of the next photo. This means that for 60% overlap, the distance the aircraft needs to travel between exposures is 0.4 Fcl, or

0.4 (36 Alt / Fl)

or

14.4 Alt / Fl.

For LALSR purposes it is perhaps better to calculate overlap in terms of seconds between exposures. It is difficult to measure visually the distance an aircraft has flown from the ground, but one can count or measure the time it takes to cover this distance if the aircraft velocity is known. This time (Ol) is obtained by dividing the distance between exposures by the aircraft velocity along the flight line:

Ol = 51.85 Alt / (Fl) (v)
sec ubf m mm Kph.

If different percentages of overlap are needed, the equation changes to

Ol = (1 - % overlap as a fraction) 3.6 Alt / (Fl) (v).

For example, if we want 20 percent overlap, then we use 0.8 as the interval by which to multiply the remainder of the equation to get the proper time interval in seconds. Overlap was further discussed in the section on surveying and mission planning.

END

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